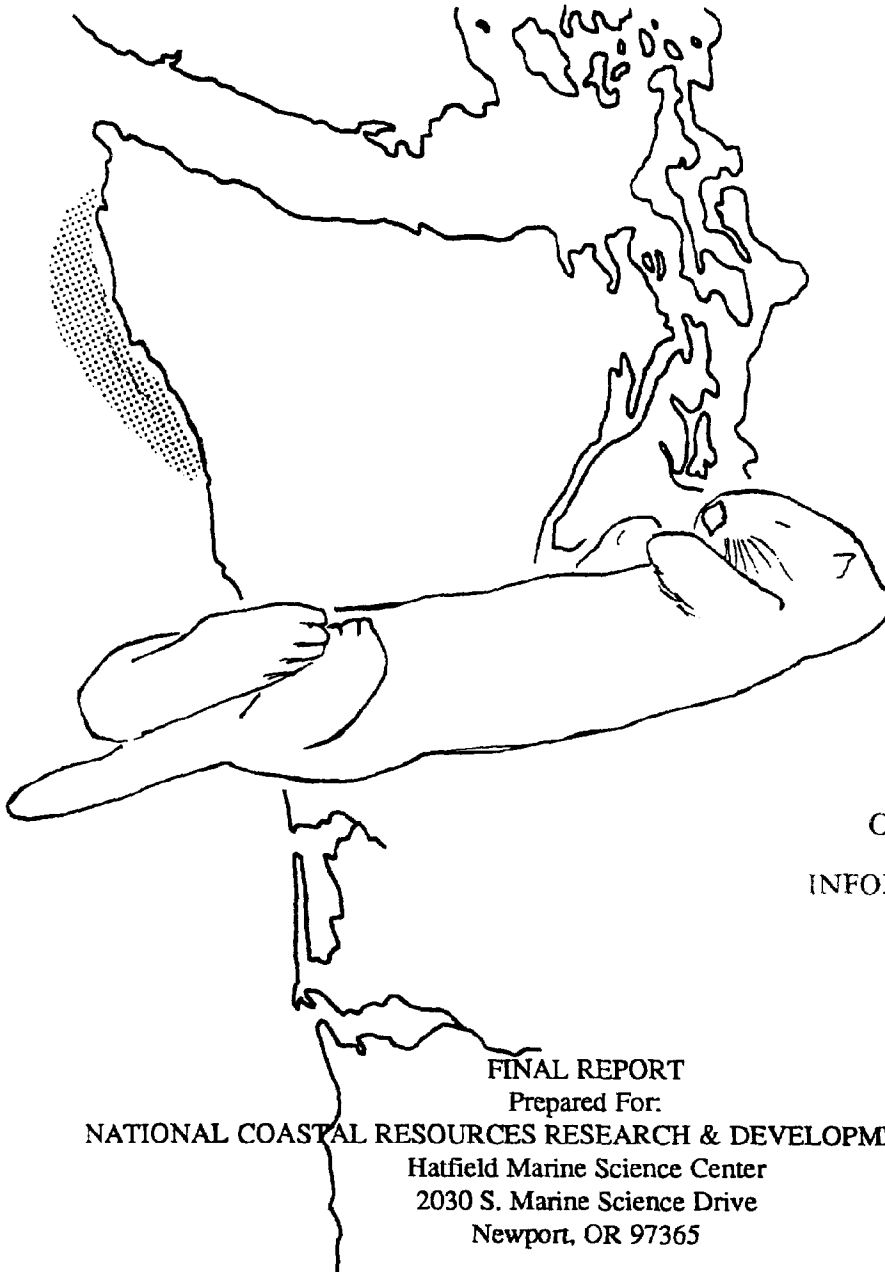# SEA OTTERS IN WASHINGTON:
DISTRIBUTION, ABUNDANCE, AND ACTIVITY PATTERNS

C. Edward Bowlby
Barry L. Troutman
Steven J. Jeffries

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Marine Mammal Investigations
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COASTAL ZONE

INFORMATION CENTER

FINAL REPORT
Prepared For:
NATIONAL COASTAL RESOURCES RESEARCH & DEVELOPMENT INSTITUTE
Hatfield Marine Science Center
2030 S. Marine Science Drive
Newport, OR 97365

September 1988

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EXECUTIVE SUMMARY

This report summarizes the current knowledge of sea otters, *Enhydra lutris*, off the coast of Washington State. Sea otters were extirpated from Washington in the early 1900s by commercial hunters. Historically they had ranged from the mouth of the Columbia River to Point Grenville, with fewer numbers found north to Cape Alava, Neah Bay, and as far east in the Strait of Juan de Fuca as Discovery Bay. In 1969 and 1970 a total of 59 otters from Alaska were transplanted to Washington and released at Point Grenville (1969) and La Push (1970). Sixteen known mortalities out of the 29 individuals released occurred within days of the first transplant, due mostly to hypothermia caused by fur soiled in transit. Improved transport conditions and use of holding pens alleviated this problem in 1970.

The status of the transplanted otters was not monitored during the first seven years following their release, although some opportunistic sightings were reported. From 1977 to 1985 five annual surveys were conducted using combinations of boat and ground counts. These surveys showed that the population was growing and had moved north of the release sites.

In 1986 and 1987 the Washington Department of Wildlife conducted an intensive monitoring program to assess the current status of the sea otter population and their habitat needs in light of proposed oil and gas leasing off the coast. Combined air and ground surveys were conducted monthly from spring through fall to identify distribution and abundance patterns. Four areas of known otter concentration (Cape Alava, Sand Point, Cape Johnson and Duk Point) were monitored daily from shore promontories. Otter activity states were scan sampled at hourly intervals to determine activity budgets and food habits as an indication of habitat quality.

Results of this study revealed that the transplanted population had increased to a 1987 high count of 107 individuals (including both dependent and independent otters). Based on calculations of a "missed index" from ground-truthing aerial counts, the total population was estimated to be 136. Early spring appeared to be the peak pupping season with 16 observed in 1986 and 17 in 1987 (3 additional late summer pups brought 1987's total to 20). The amount, if any, of winter pupping is unknown and mortality rates remain in question.

Sea otters ranged along 70 km of the Washington coast, from Destruction Island north to Point of the Arches, and showed

seasonal population shifts. The Cape Alava region was apparently used by otters year-round, with the majority of the population residing there in early spring. By late spring/early summer a population shift occurred with animals moving south into the Cape Johnson region. Starting in late summer a reverse pulse transpired and by September the majority once again resided around Cape Alava. This area is apparently favored for overwintering the severe winter storms due to the protection afforded by Ozette and Bodelteh Islands and localized *Macrocystis* kelp beds.

Activity-time budgets showed Washington otters spending 9.5-11.2% of their daylight hours foraging, 62.6-66.1% resting, and the remainder in general activities. This daytime pattern of low feeding frequency is similar to areas in Alaska and California where otters are considered to be below equilibrium density and not food limited. It contrasts with other areas considered to be at carrying capacity (eg. Amchitka Island) where otters have to spend 50-55% of their diurnal activity budgets feeding in a resource limited habitat. However this interpretation of resource availability can be severly biased if a disproportionate amount of foraging occurs nocturnally.

Washington otters preyed exclusively on macroinvertebrates: clams, chitons, sea cucumbers, octopus, crabs, and urchins. Success rates of their foraging dives were high, averaging 88.5-89.4%, although the majority of the prey consisted of small to medium size items (< 10 cm in dimension).

Although Washington sea otters may not be currently resource limited, evidence from benthic surveys conducted in 1987 suggests that they have substantially reduced available prey biomass within their range. Subtidal communities sampled within the primary otter range ($\bar{x}$ otter sightings per aerial survey $\geq$ 3) had roughly half the prey biomass compared to secondary range areas ($\bar{x}$ < 3). Areas just north of the current otter range revealed far richer habitats with biomass approximately ten times greater than within the primary range. With this high quality habitat to the north and the apparently reduced resource within the current range, otters could be expected to undergo a range expansion in the near future.

Because the Washington sea otter population is still small and occupies a limited range, they are classified as an "Endangered Species" by the State of Washington. The population has grown, albeit slowly, roughly tripling the numbers effectively transplanted 17 years ago. Although continued growth would be expected, several potential threats to the population loom in the future. If and when the population undergoes a range expansion, reoccupying their former historical sites, conflicts may arise with

certain fisheries. Bordering the northern otter range, from Point of the Arches north to Cape Flattery, is a Makah tribal gillnet fishery with marine set nets. Otters are particularly susceptible to entanglements in gillnets and this has caused significant mortality in the California population. Also if the otters move north or south they will eventually overlap commercial and sport fisheries for Dungeness crabs, sea urchins, and razor clams, leading to resource competition.

The entire population may be at even greater risk from the proposed leasing of offshore waters for oil and gas development in Washington and Oregon (Outer Continental Shelf Lease Sale #132). Sea otters are known to be the most vulnerable marine mammal species to direct oil contamination. This sensitivity is a product of their anatomy; they lack a blubber layer and rely solely on their dense fur to provide thermal insulation to ambient temperatures. The insulative properties are lost with with oiling, resulting in thermal stress which usually leads to hypothermia and death, depending on the amount of oiling. Any oil spill affecting the limited range of the Washington sea otter could therefore jeopardize a major portion if not the entire population.

While this study addressed several important aspects of sea otter demographics and behavioral ecology, additional studies are required to continue monitoring the health of the Washington population and to fill in several important data gaps. Combined air and ground surveys should be continued to assess the population trends, distribution, and peak pupping periods. The offshore component of their range, winter distributional patterns, and mortality rates and causes need to be investigated. The questions of individual food habits and movement patterns of Washington otters could be addressed using radiotelemetry and tagging techniques. Radiotelemetry would also evaluate nocturnal activity patterns and correlated with diurnal activity budgets would resolve the question of resource levels within the habitat. Instrumenting females would answer the question of pupping frequency, whether annual or biennial. Food habit studies and benthic surveys should be continued to provide additional assessments of habitat quality and to document any change in subtidal community structure. Coastal aerial mapping of kelp beds should be initiated to establish baseline data to document otter/kelp interrelationships. Future threats to the population, such as fishery interactions and offshore oil and gas developments, should be evaluated and management plans developed accordingly.

INTRODUCTION

A) Goals of Present Study

The goals of this study were to assess the current status and future outlook of the transplanted sea otter (*Enhydra lutris*) population in Washington State. Specific project tasks included monitoring otter abundance and distribution and evaluating their activity-time budgets and food habits as an indication of habitat quality and resource use.

B) Early History of Sea Otter Populations in Washington

Before the arrival of Europeans in the Pacific Northwest, sea otters occupied a nearly continuous range along coastlines bordering the North Pacific Ocean, from Baja California to the northern islands of Japan (Kenyon 1969). Native American and Asian peoples hunted otters but took relatively small numbers for food or clothing. Following early voyages of exploration in the North Pacific, notably those by Vitus Bering in 1741 and James Cook in 1778, a lucrative trade in sea otter pelts began which resulted in heavy exploitation of most otter populations (Ogden 1941; Lensink 1962). By 1911, when a treaty protecting sea otters was signed by the nations of the United States, Great Britain, Russia and Japan, only a few remnant populations of otters remained. Excellent historical accounts of this early era of fur trading can be found in Scammon (1968) and Pethick (1979).

Historically Washington sea otters were once found in abundance and commercially hunted along the central portion of the outer coast between Grays Harbor and Point Grenville (Scheffer 1940; Scammon 1968; VanSyckle 1982) (Fig. 1). Otter populations along the remainder of the coast were reported to be sparse, although early reports by Lewis and Clark and others suggest that another population concentration may have existed near North Head, immediately north of the mouth of the Columbia River (Scheffer 1940).

Scheffer (1940) and Kenyon (1969) thought it unlikely that Washington sea otters ranged any distance from the outer coast and reported that historical records indicated they never occurred in the greater Puget Sound area (Fig. 1). However a 1790 Spanish exploratory cruise led by Ensign Manuel Quimper reported seeing and trading for live sea otters at Discovery and Dungeness Bays, and even more were collected at Neah Bay (Wagner 1933). Thus some otters had ranged along the Straits of Juan de Fuca as far east as

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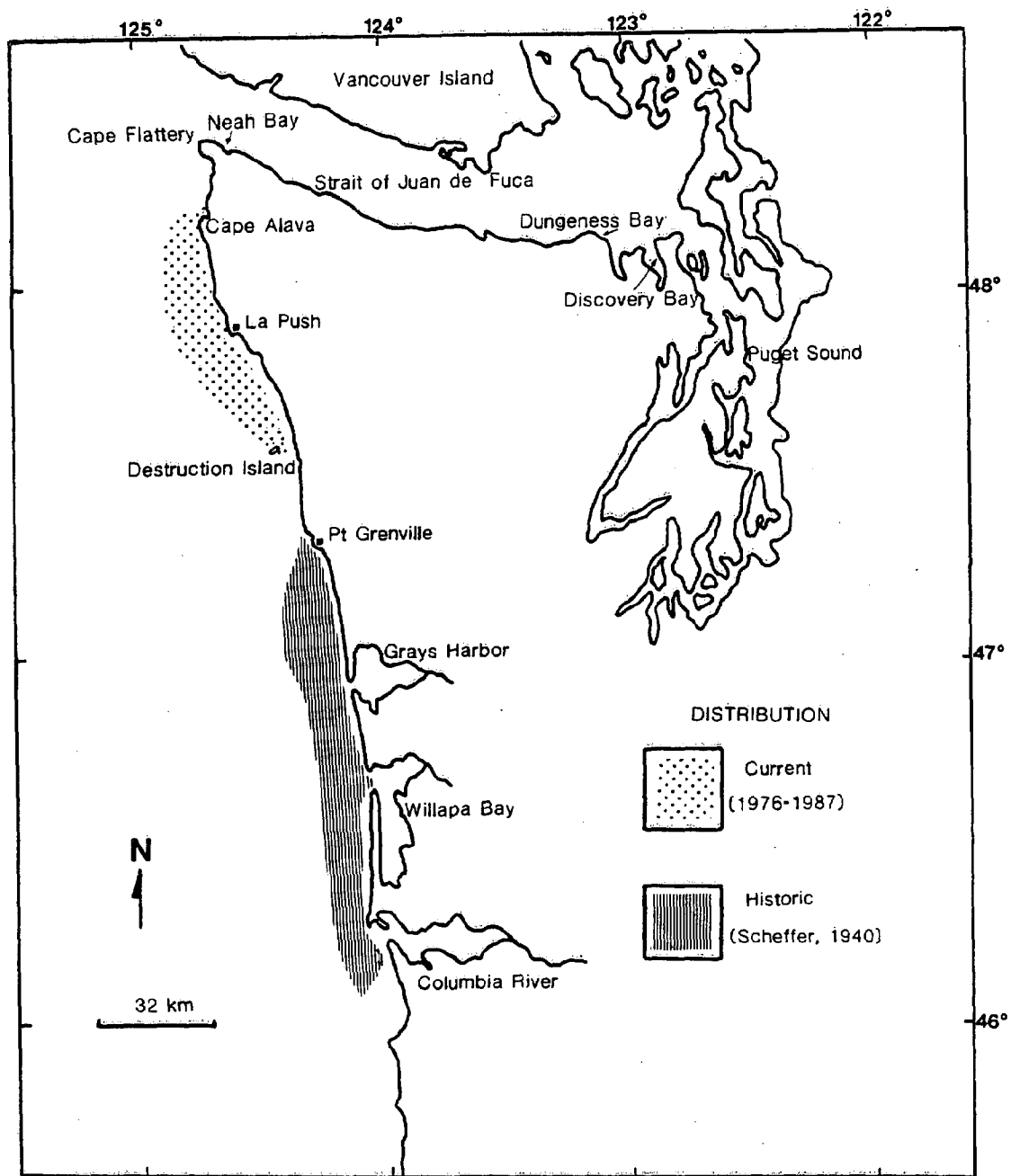
Figure 1. Historic and current distribution of sea otters in
Washington State.

Discovery Bay, although apparently not in numbers sufficient for the subsequent commercial fur trade.

Archaeological evidence reveals that prehistoric Indians also hunted sea otters along the northwest coast of Washington. Otter bone remains were excavated from kitchen middens at Cape Alava (Huelsbeck 1983) and at Hoko River, east of Neah Bay (Wigen 1982)(Fig. 1). A carved wooden sculpture inlaid with over 700 sea otter teeth was also discovered at the Cape Alava archaeological site (Kirk and Daugherty 1974). Interpretation of hunting practices and prey availability from examinations of kitchen middens can be biased, however, if trade items from other locations were also deposited. Swan (1870) recorded 19th century Makahs of Cape Flattery conducting trade with the Quinault Indians (near Point Grenville) for sea otter pelts, apparently indicating the sparcity or absence of otters near the Cape at that time. However if pelt trading occurred prehistorically, presumably the transactions would have consisted of pelts without skeletal remains. Therefore the presence of midden bones must indicate some amount of local hunting for sea otters at these northwest coast sites.

Faunal analyses of the Cape Alava kitchen middens revealed that the Makahs were premier ocean hunters, relying primarily on fur seals (*Callorhinus ursinus*) and whales with sea otters playing a minor role (Huelsbeck 1983). However the analyses only go back 500 years before present and Makahs had occupied the area continuously for some 2000 years (Daugherty and Fryxell 1967). Their hunting during this earlier 1500 year period could have significantly reduced the resident otter population as has been documented for aboriginal Aleut hunters with Amchitkan otters (Simenstad et al. 1978). This could account for the sparcity of otter remains in the more recent 500 year stratigraphic record as well as the historical low numbers reported along the northwest coast.

The size of Washington's original sea otter population has never been established. Although fur-trading company records have been examined they were too vague regarding the sources of their acquired skins to be of much assistance in this regard (Scheffer 1940). Historic otter populations may have been sizeable, however, since early accounts mention individual "herds" ranging from 50 to nearly 400 animals (Scheffer 1940). Overhunting had severely reduced Washington's otter population by the late 1800s and in 1903 the last of the professional sea otter hunters in the state had quit hunting (Van Syckle 1982). The last known otters in Washington were taken in Willapa Bay in 1910 (Scheffer 1940). Washington's otters, like those in so many other areas, had been totally extirpated.

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C) Reintroduction of Sea Otters into Washington

In 1969 sea otters were reintroduced into Washington waters
following a 59 year hiatus. The goal of the reintroduction
was to reestablish a self-sustaining population of this once
native species within its ancestral range. The transplant
occurred on 31 July and resulted from a joint effort by the
Washington and Alaska Wildlife Departments, the Atomic
Energy Commission, the Department of Defense, and the U.S.
Fish and Wildlife Service. The transplant stock had been
acquired from a sizeable population at Amchitka Island in
Alaska's Aleutian Islands chain. A total of 29 animals (19
females; 10 males) was released at Point Grenville, a
location where otters had historically been abundant.
Unfortunately, within a few days 14 of the transplanted
otters were found dead on the beaches. Apparently most of
these animals succumbed to a combination of stress and
hypothermia, with the later caused by deteriorated pelage
condition acquired during their transportation from Alaska.
Two animals killed by gunshot were found some time later,
bringing the total loss to at least 16 of the initial 29
animals (Kenyon 1970). With the realization that the small
surviving nucleus group would probably be incapable of
producing a healthy, self-sustaining population, a second
transplant consisting of 30 animals (22 females; 8 males),
also derived from the Amchitka Island population, took place
on 21 July, 1970 near La Push (at James Island), at the
mouth of the Quillayute River.

Valuable lessons had been learned from the near failure of
the 1969 transplant, with transport and handling
methodologies significantly improved in the interim. As a
result, the 1970 effort was highly successful and no
apparent mortality was observed following the transplant.

D) Post-transplant Surveys of Washington's Sea Otter
      Population

To facilitate depiction of data from post-transplant
sightings and surveys, we subdivided the Washington coast
into 6 regions as shown in Figure 2. These regions are
based on observed patterns of sea otter distribution
relative to natural landmarks on the coast. Rock numbers
refer to designations by the U.S. Fish and Wildlife Service
(1970) for the Washington Island Wilderness system.

General distribution and abundance of post-transplant
otters, from 1970-1985, are shown by histograms in Figures 3
and 4. Highest counts are shown by year (Fig. 3) and region
(Fig. 4) with pup numbers noted within parentheses in the
respective bar graphs. References for each count are shown
by numbered boxes above the year category and are detailed

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STATE OF WASHINGTON

DEPARTMENT OF WILDLIFE

600 North Capitol Way, GJ-11 ● *Olympia, Washington 98504-0091* ● *(206) 753-5700*

DATE: October 3, 1988

TO: Distribution

FROM: Ed Bowlby

SUBJECT: Sea Otter Report

Enclosed is a copy of <u>Sea Otters in Washington: Distribution,</u>
<u>Abundance, and Activity Patterns</u>. Please feel free to make
any comments.

Enc.

Washington Department of Wildlife
MARINE MAMMAL INVESTIGATIONS
7801 Phillips Rd. S.W.
Tacoma, WA 98498

REGIONS

VI

Tatoosh Isl.

Neah Bay

Cape Flattery

Rock #109

Point of the Arches

V

Bodelteh Isl.

Duk Point

Ozette Isl.

Cape Alava

Rock #192

Sand Point

IV

Ozette Lake

Rock #222

Jagged Isl.

III

Cape Johnson

James Isl.

La Push

II

I

Rock #458

Destruction Isl.
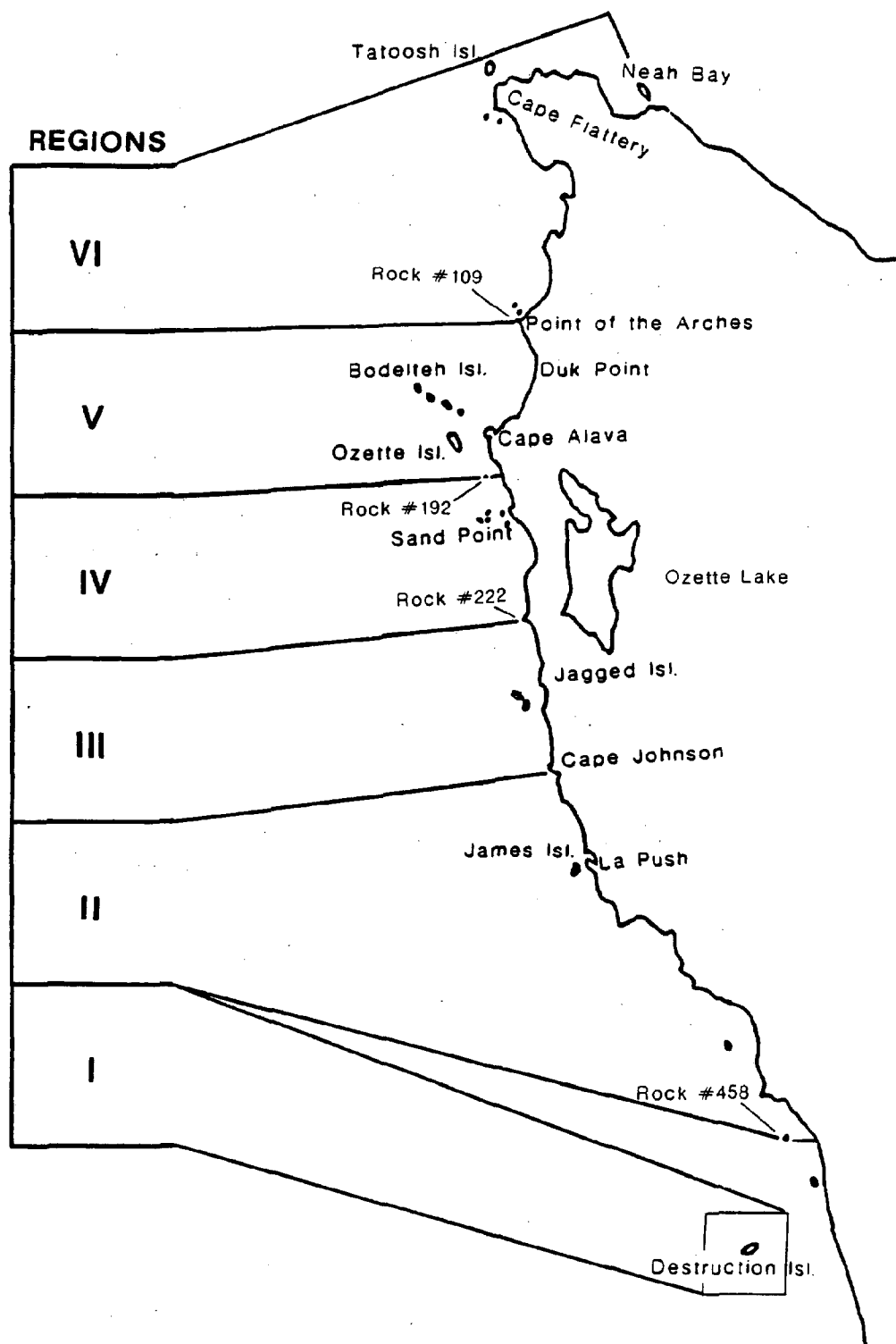
Figure 2. Regional demarcations of the Washington coast.

MINIMUM POPULATION COUNTS

18 —
14 —
10 —
6 —
2 —

45   60 48 46

(2) (2)   (4) (1) (2) (1) (1)   (4) (1) (2)

| 1 | 2 | 3 | 3 | 4 | 5/6 | 3 | 7 | 8/9 | 10 | 11 | 12/13 | 14 | 15/16 | 17/18 | 19/20 |

1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985

ALL REGIONS
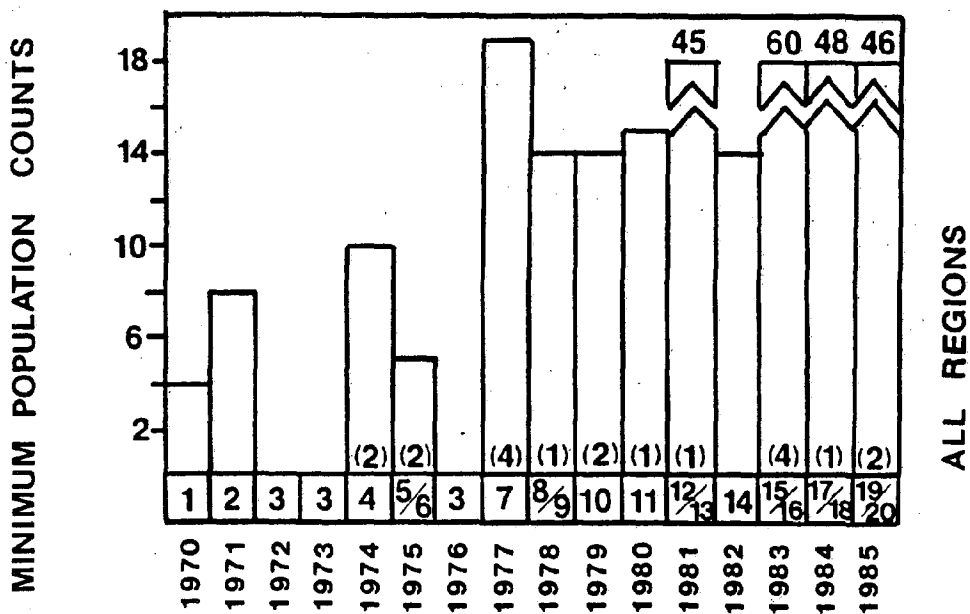
Figure 3. Minimum population counts of Washington sea otters, 1970-1985.
Numbers in parentheses indicate pup counts included in the
total. Numbered boxes above each year category refer to re-
ferences in Appendix 1. When 2 sets of numbers appear, the
first refers to the source of the total count and the second
to the pup count.

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Figure 4. Regional counts of Washington sea otters, 1970–1985. Numbers in parentheses indicate pup counts included in the total. Numbered boxes above each year category refer to references in in Appendix 1. When 2 sets of numbers appear, the first refers to the source of the total count and the second to the pup count.

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in Appendix 1. When two sets of numbers appear, the first refers to the source for the total count and the second to the pup count. High regional counts (Fig. 4) often occurred during different months within a year and because otters can and do move between regions, the yearly coast-wide total (Fig. 3) cannot be a simple summation of the respective regional totals. For this reason minimum population totals were derived almost exclusively from single day surveys. As such they are necessarily conservative.

Best population counts of the entire coast, between 1970 and 1985, appear in Figure 3. The low numbers from 1970-1976 are partially a result of opportunistic sighting effort with only portions of the coast surveyed. Only isolated observations made by a variety of individuals exist for this period. From this pool of information, we judged and included only those sightings deemed valid, based on a) known observer experience or b) sufficient identification detail provided, in Figures 3 and 4. Coastwide coverage from 1977-1980 revealed numbers fluctuating between 14-19 otters. After 1980 sightings increased significantly. The highest post-transplant count of 60 individuals occurred in 1983. Although Jameson et al. (1986) reported a 1985 count of 65 otters, this was based on summing his July 24-27 boat and shore count of sea otters with S. Jeffries aerial count of Sand Point on July 10. Since otters can make substantial net movements over a two week period and summation of these counts could likely have resulted in double-counting, we extracted the aerial count, leaving a total surface count of 41 individuals.

Although no systematic sea otter surveys were conducted between 1970 and 1976, the opportunistic sightings revealed some insight into otter distribution. Otters were seen as far north as Cape Johnson, Region III, by 1970 (Fig. 4), and two dead pups washed ashore near Cape Alava, Region V, in 1975. A small population appeared to have colonized Destruction Island, Region I, since at least 1971, but no otters were sighted along the mainland south of Middle Rock, the southern boundary of Region II. The absence of any confirmed sea otter sightings south of Destruction Island in the years following the 1969 transplant at Point Grenville suggests that the animals introduced there either emigrated or perished. This absence of sea otters between Point Grenville and Destruction Island was also confirmed by results of intensive shore-based and aerial surveys during a 1984 and 1985 seabird monitoring program (Speich et al. 1987).

The first systematic post-transplant survey of Washington's sea otters was initiated in 1977 by Ronald Jameson (Jameson et al. 1982). A total of 5 surveys were conducted between 1977 and 1985 (Jameson et al. 1986). These surveys

incorporated a combination of boat and ground counts
conducted over a period of several days each year, and
attempted to survey all potential sea otter habitat on the
Washington coast.

Another major source of the post-transplant population came
from data collected by Steven Jeffries during aerial surveys
of Washington's coastal harbor seal population (Washington
Dept. Wildlife unpublished flight logs). Although these
aerial surveys, begun in 1977, were directed at censusing
harbor seals, other marine mammals including sea otters were
also recorded when observed. Sea otter sightings were
recorded during 34 complete and partial coastal flights
between 1977 and 1985.

After 1977 increased sea otter numbers were seen in the
northerly Regions, III-V (Fig. 4), and since 1981 the
majority have resided there. From 1970-1985 the northern
extent of their range was Cape Alava, Region V. Only two
otters were sighted in Region VI, one near Tatoosh Island in
1982 and one in Neah Bay in 1985, and both of these were
thought to represent the wanderings of lone animals rather
than range extensions.

The rate at which the reproductive portion of the population
dispersed from the initial transplant sites to inhabit its
current range is not clear from survey data obtained prior
to 1986. Jameson et al. (1986) reported that females with
pups were not seen at Cape Alava until 1983 while other
records (Fig. 4) indicate the presence of dependent pups
there as early as 1978. This discrepancy could have
resulted from differences in the seasonal timing of the
surveys involved (e.g. mother/pup pairs moving into or out
of areas or difficulties in detecting large dependent pups
in late season surveys).

Sea otters at Destruction Island consistently maintained a
population of 7-10 individuals from 1977-1985 (ignoring the
single sighting from a ship in 1979). Considering that no
otters were sighted in Region II from 1981-1985, Destruction
Island otters might be considered a disjunct sub-population
from mainland otters to the north.

STUDY AREA

The study area extended along the outer Washington coast
from Destruction Island north to Cape Flattery (Fig. 5),
including all known areas within the current sea otter range
(Jameson et al. 1982; Jeffries unpub. data). Most of this
coastline is designated as a coastal corridor of Olympic
National Park with smaller portions administered as tribal
lands of the Makah, Ozette, Quileute, and Hoh Indian
Reservations. The offshore rocks and islands are U.S. Fish
and Wildlife National Wildlife Refuges (Flattery Rocks and
Quillayute Needles National Wildlife Refuges) making up part
of the Washington Island Wilderness system (U.S. Fish and
Wildlife Service 1970).

This exposed, rocky coastline is characterized by short
stretches of sandy or cobbly pocket beaches separated by
headlands, subtidal rock reefs and numerous offshore rocks
and islands. The area is representative of a high wave-
energy, rocky-shore ecosystem. Aleutian frontal systems
sweep the coast during winter, while calmer conditions
prevail during summer when the North Pacific High dominates
and coastal fog is not uncommon (Lilly 1983). Mean surface
temperatures along the coast range from 12 - 13° C during
summer and 8 - 10° during winter (U.S. Dept. Comm. 1986).
Nearshore water depths are shallow and the rocky-bottomed
areas support kelp patches dominated by species of
Macrocystis and *Nereocystis*. The bottom slopes off
gradually with the 10 fathom (18 m) isobath occurring at an
average offshore distance of 1.8 km and the 20 fathom
isobath at 10 km.

Four shore sites were chosen for primary monitoring areas
based on known otter abundance (Jameson et al. 1982;
Jeffries pers. comm.) and advantageous viewing perspective
(Fig. 6). Site 1, the Cape Alava complex, was monitored
from atop Cannonball Rock. This headland, with a 42 m
elevation, afforded panoramic views of Ozette and Bodelteh
Islands. Site 2, at Sand Point, was 4 km south of Cape
Alava and had an observation overlook height of 6.7 m. Site
3, at Cape Johnson, was 15 km south of Sand Point. An
unnamed headland north of the Cape, hereinafter called
"Bluff Point", afforded a vantage height of 85 m. Site 4,
Duk Point, immediately north of the Cape Alava site, had a
vantage point of 37 m. At each of the sites natural
landmarks were used to arbitrarily divide the observation
areas into 4 inner and outer zones (Fig. 7 - 10) in order to
provide reference points for observers and to facilitate
counts of animals. Our shore sites and viewing zones roughly
corresponded in size to Estes et al. (1986) "study areas"
and "viewing areas", respectively.
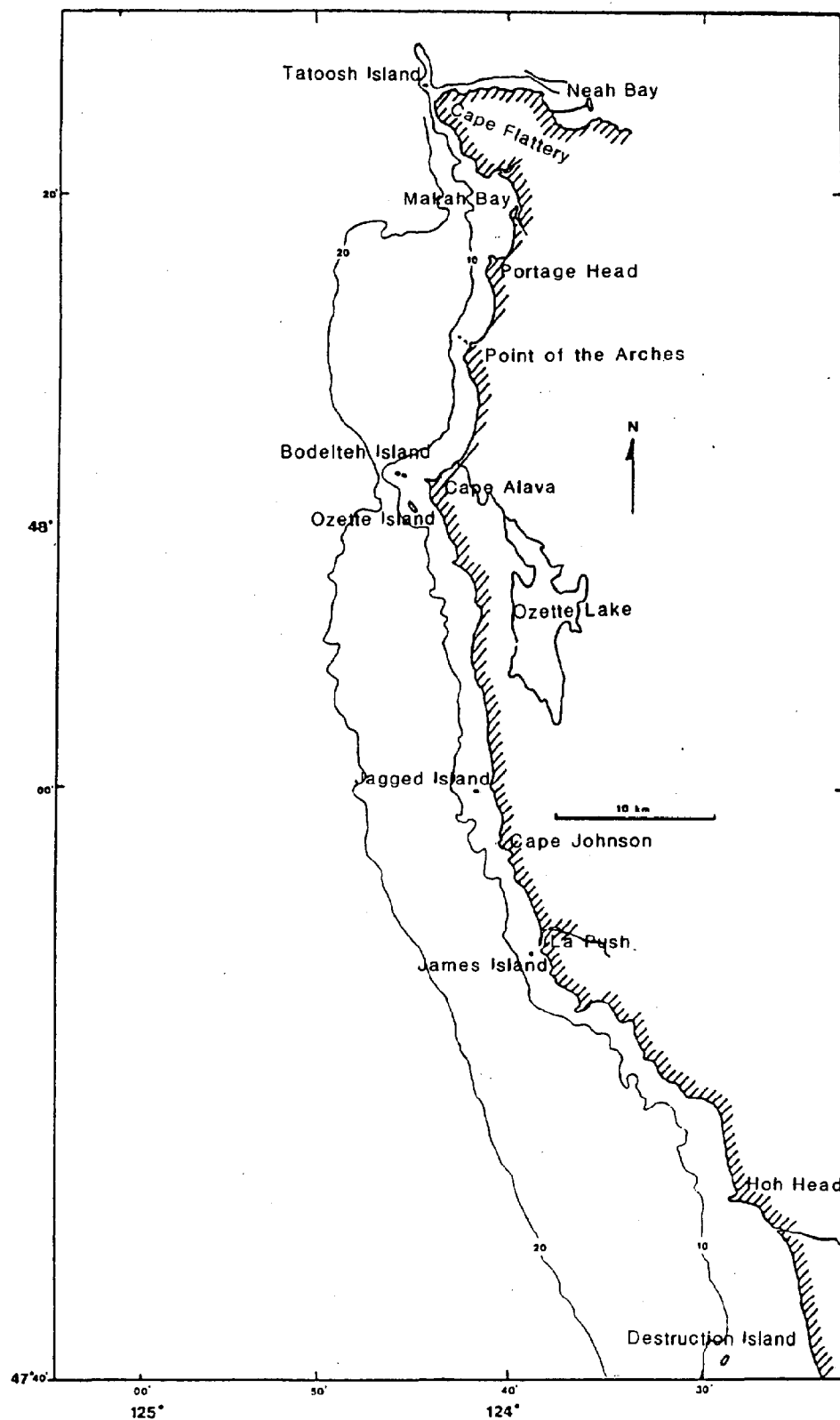
Figure 5. Washington coast study area, Destruction Island to Cape Flattery. Bathymetric contours (in fathoms) based on U.S. Department of Commerce Nautical Chart No. 18480.

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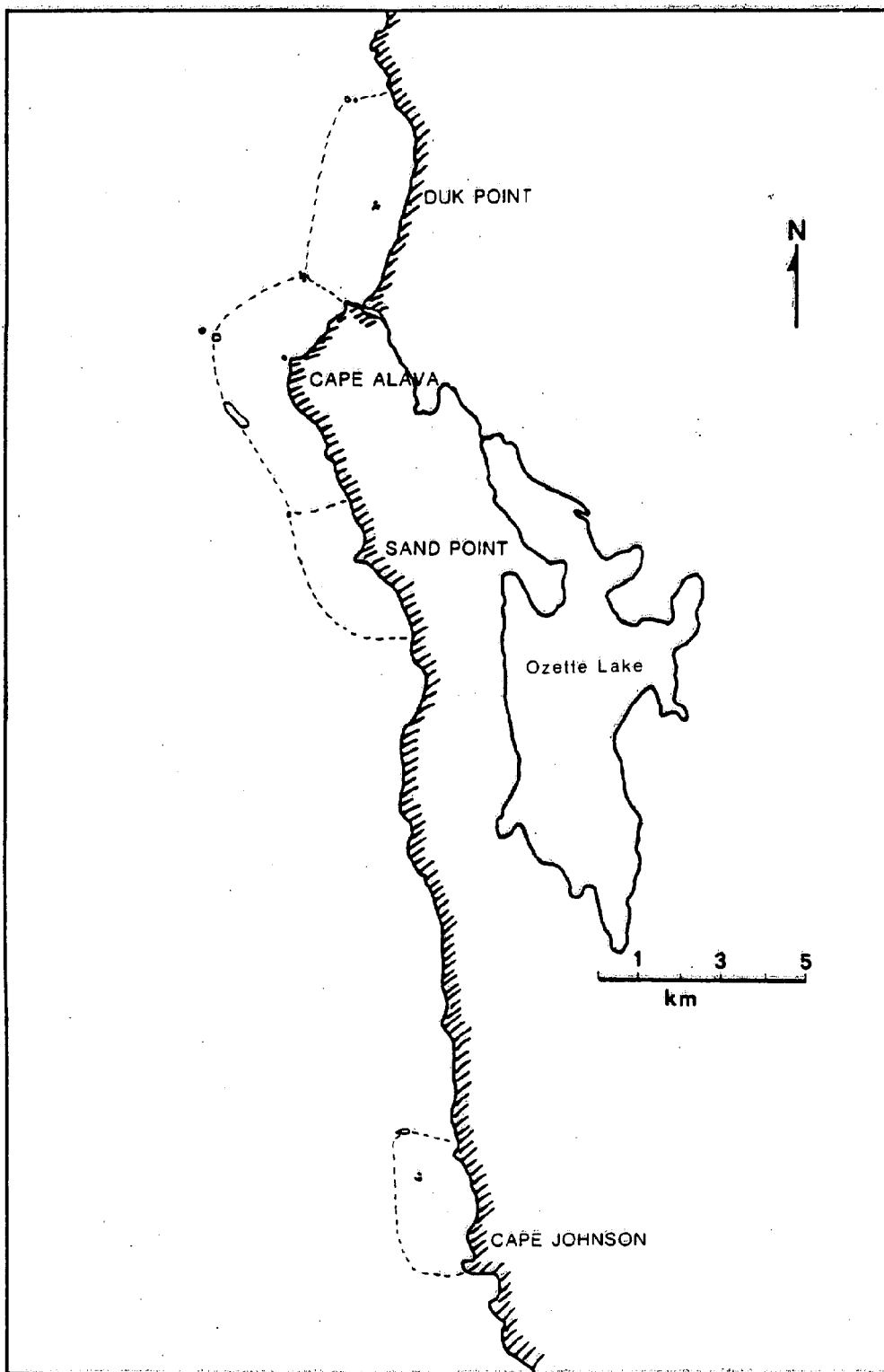
Figure 6. The four shore monitoring sites along the Washington coast.
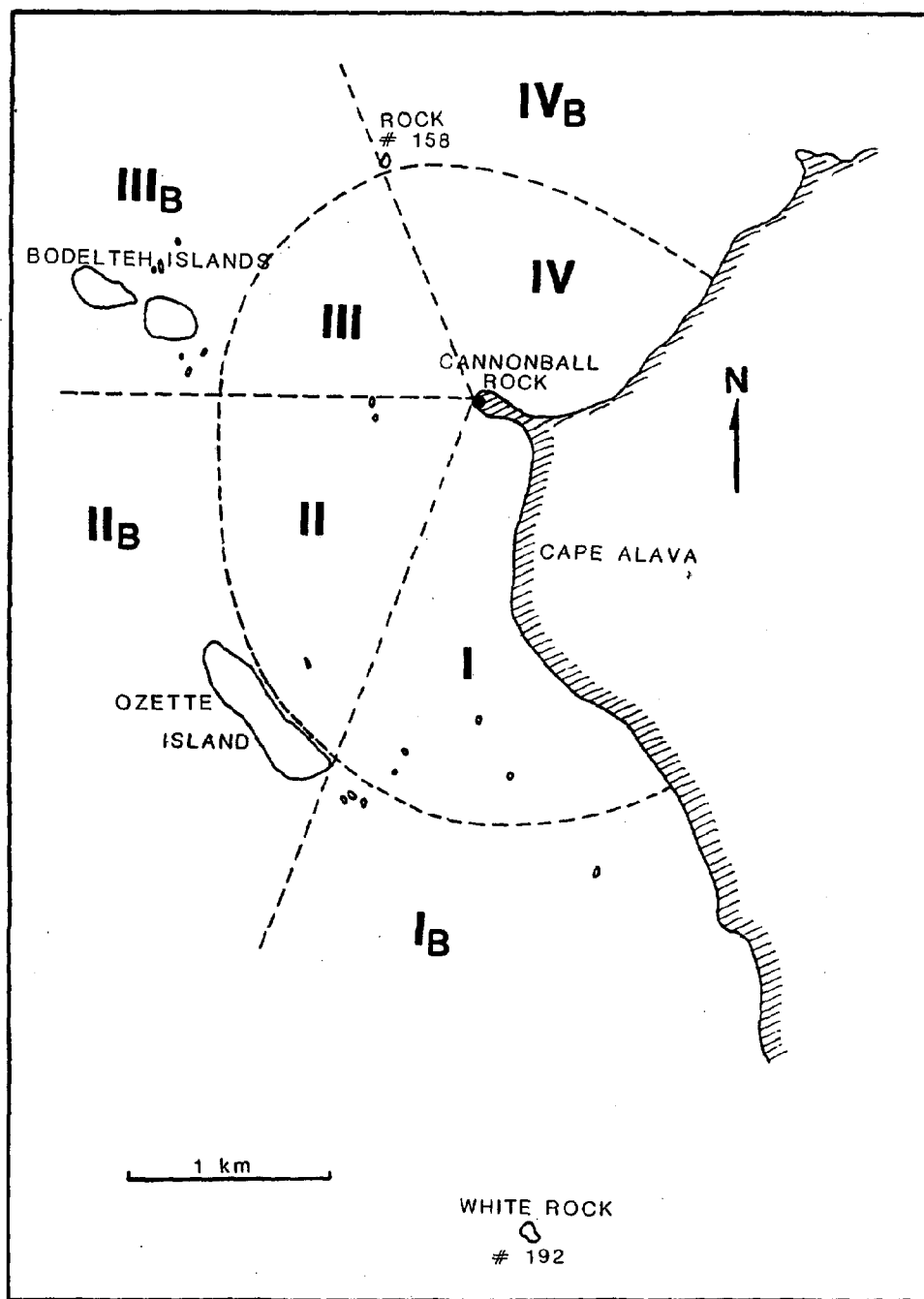
Figure 7. Cape Alava monitoring site and scan zones.
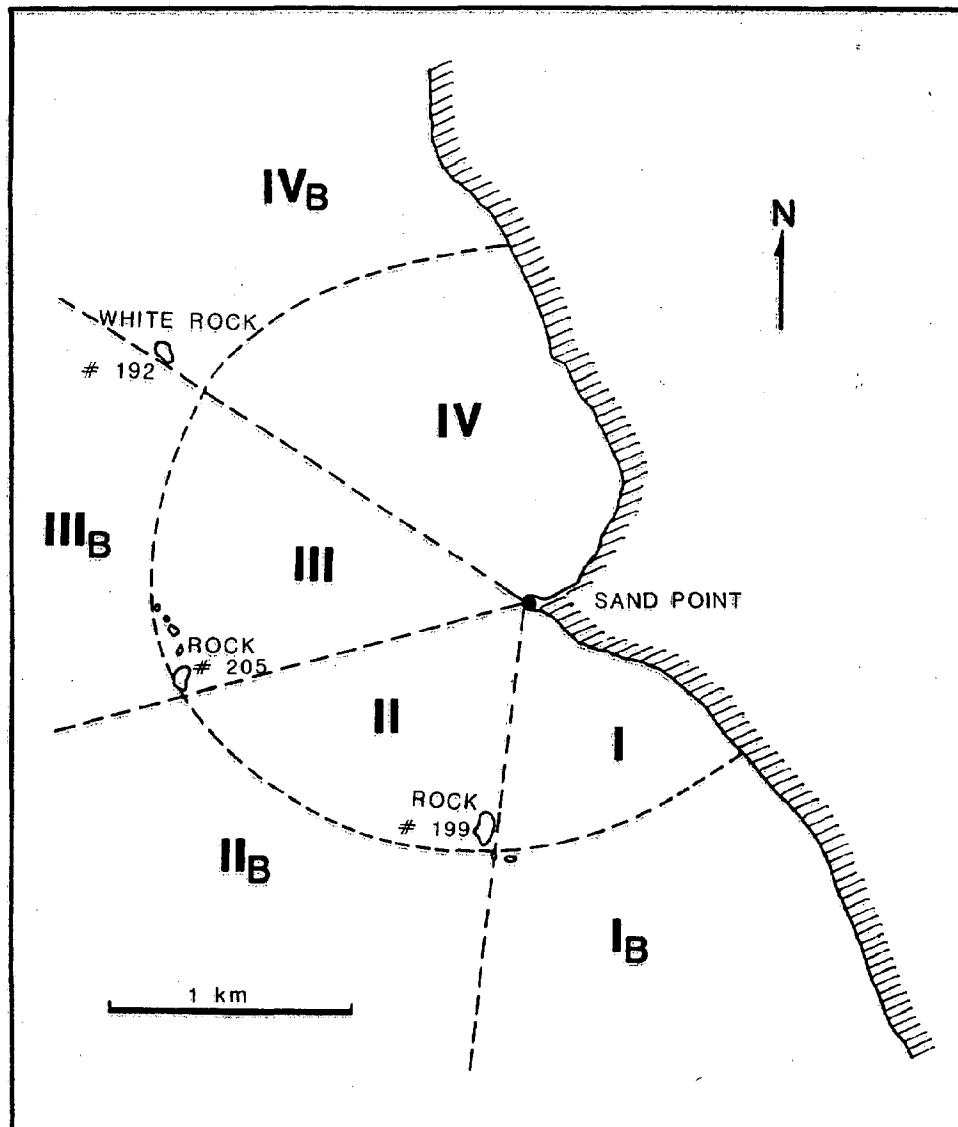
Figure 8.   Sand Point monitoring site and scan zones.
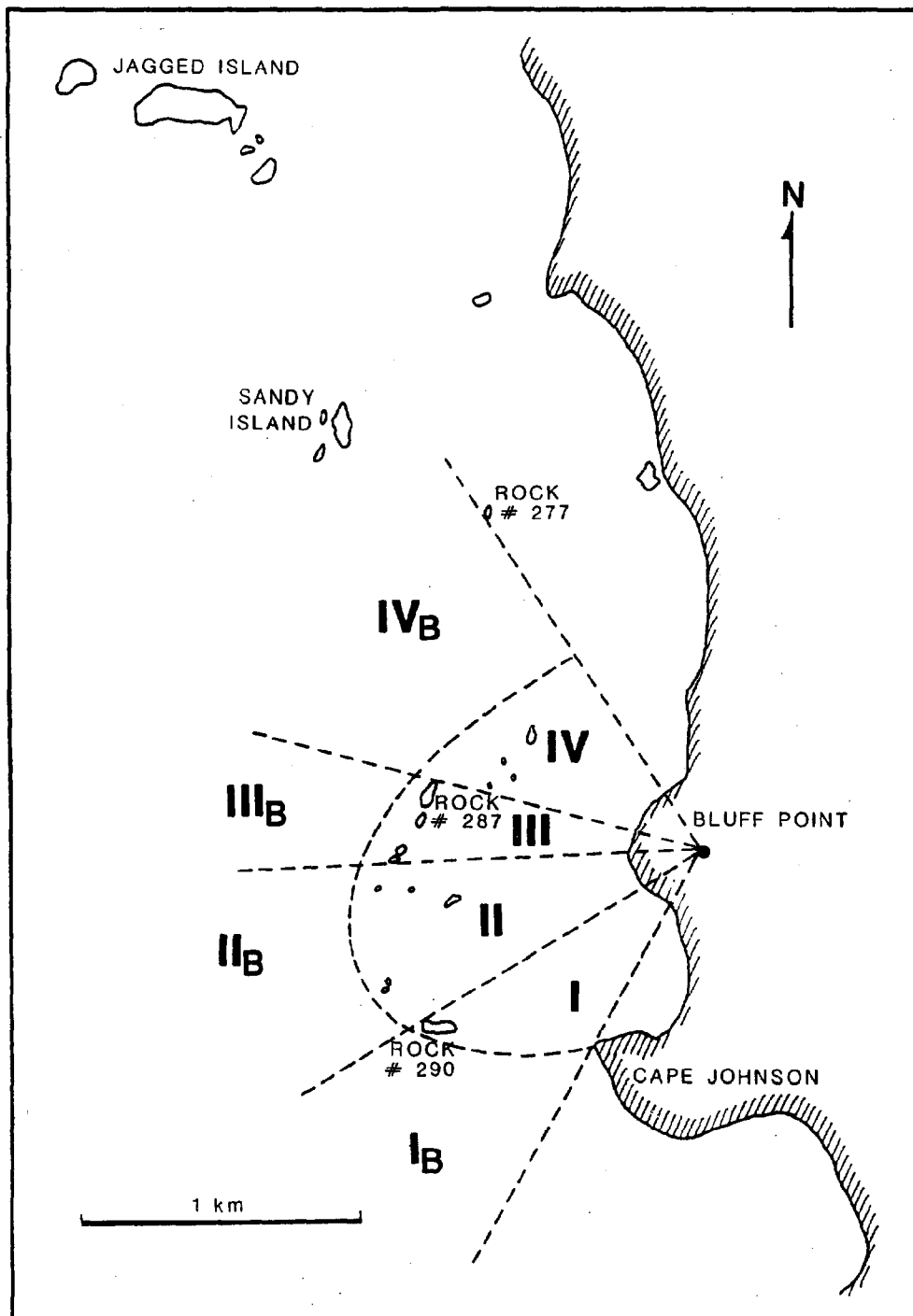
Figure 9. Cape Johnson monitoring site and scan zones.
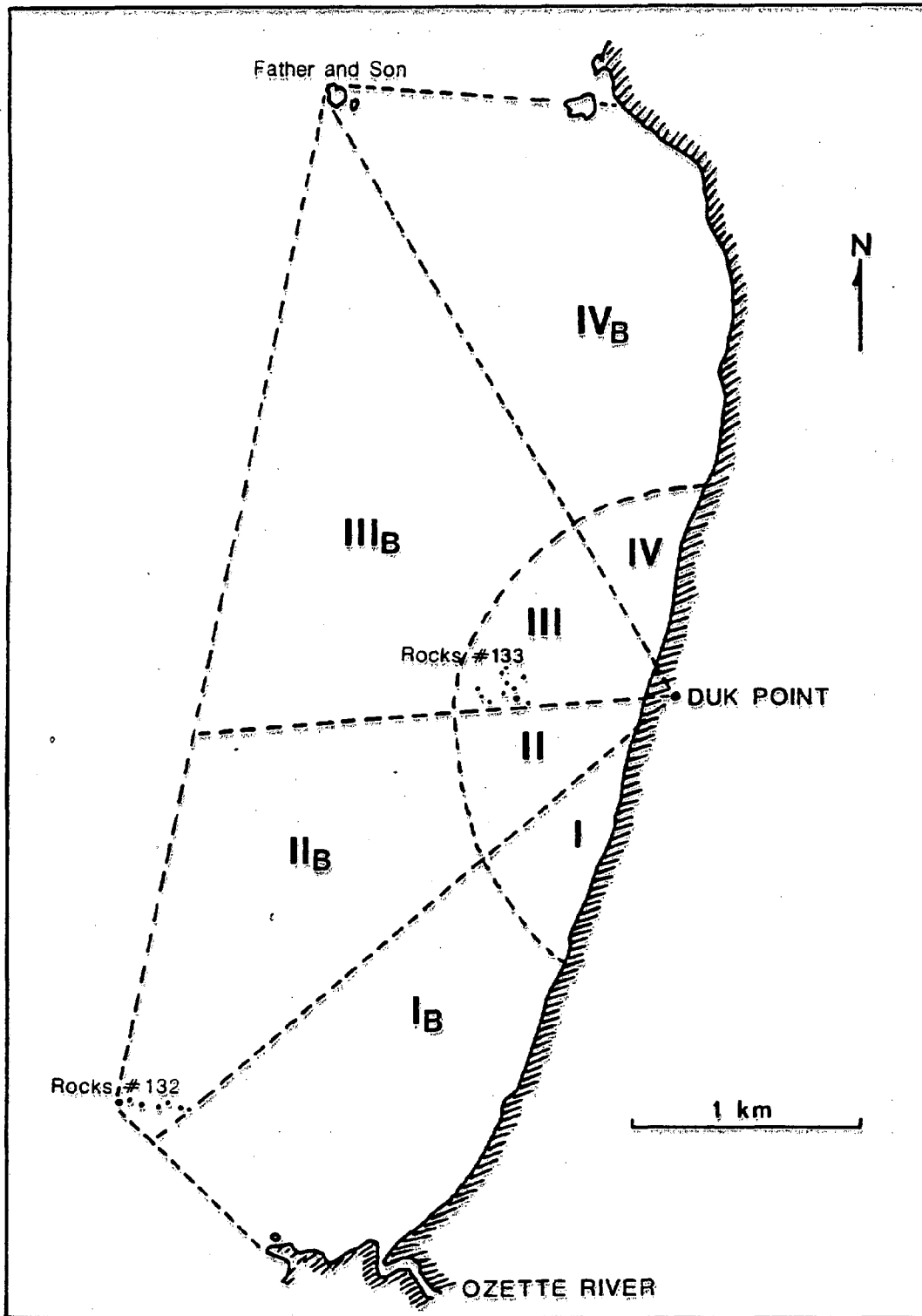
Figure 10. Duk Point monitoring site and scan zones.

METHODS

A) Aerial Surveys

With the small size and limited range of the sea otter
population off the Washington coast (Jameson et al. 1982),
censuses of the entire population were attempted during
aerial surveys. Monthly aerial counts of all areas within
the 10 fathom isobath, the known Washington sea otter range
(Jameson et al. 1982), were conducted from May to August in
1986 and March to October in 1987, to assess otter
distribution and abundance. Surveys were conducted using
either a Cessna 172 or a DeHavilland Beaver aircraft and
flown at an average airspeed of 100 knots and from altitudes
ranging from 400 to 600 feet. Our survey altitudes were
higher than those used to census otters in some studies
(Estes 1977; Wild and Ames 1974; and Carlisle 1966) but well
below the maximums reported in others (Calkins 1972).
Higher survey altitudes were used to permit adequate survey
coverage of the extensive areas of otter habitat within our
study area and to reduce the likelihood of startling animals
when the aircraft was circling an area.

Surveys were flown with two observers located on the right
side of the aircraft. The primary observer occupied the
forward seat and the aft observer helped in spotting animals
and, in the absence of a third passenger, also acted as data
recorder. A separate data recorder was carried onboard,
left side aft, whenever possible. The pilot assisted in
spotting animals but was not involved in obtaining counts.
All areas of known or potential sea otter habitat between
Destruction Island and Cape Flattery, including offshore
reefs, kelp beds and islands, were overflown during each
survey. The more extensive or complex habitat areas were
circled as often as was necessary to permit adequate search
coverage and to allow counting of animals. Counts of
animals were made directly by the observers and groups too
large to count precisely were also photographed to permit
later count revisions. The time required for a complete
survey of the study area ranged from 1 to 2 hours. Classi-
fication of sea state and weather conditions were made
during each survey to permit later evaluation of survey
results. Consecutive day replicate aerial surveys were
attempted in 1987 to assess count variability.

Simultanaeous air and ground counts were conducted when
possible. The aircraft flew its normal survey routine while
shorebased observers obtained simultaneous otter counts from
the shore monitoring sites. The census surveys were
generally scheduled before noon to avoid afternoon glare and
heat-wave distortion occassionally encountered by shore

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observers.   These combined surveys were conducted to ground-
truth aerial counts and to evaluate the biases involved in
each census technique.

B)   Ground Counts and Scan Sampling

Ground monitoring were conducted at the four shore sites to
collect information on otter demographics, diurnal activity
patterns and food habits.   Monitoring was conducted from one
hour after sunrise to one hour before sunset, recording in
Pacific Daylight Savings Time (PDST).   Field work in 1986 ran
from May through August.   Three consecutive days per week
were scheduled for the first three weeks of each month,
weather permitting. The 1987 field season ran from March
through September with five consecutive field days scheduled
every other week.

Diurnal activity-time budgets were determined by scan
sampling (Altman 1974).   Scans were conducted at half hour
intervals at Cape Johnson and Sand Point and hourly at Cape
Alava and Duk Point due to their greater coverage area. To
curtail observer fatigue, off periods were scheduled for
resting.   In 1986 two hour observation sessions alternated
with two hour off periods.   In 1987, three hour observation
sessions alternated with a one hour off period.

Scan sampling of sea otter activity states followed
procedures and definitions of Estes et al. (1982) and
Packard and Ribic (1982).   Otter behaviors were categorized
into one of three activity states: 1) resting; 2) feeding;
or 3) other activity (the latter included such behaviors as
swimming, grooming, interacting, and undetermined).
Activity-time budgets and activity patterns were calculated
from these samples.

Scans were conducted using a combination of binoculars and
15-60x spotting scopes.   Binoculars were used for brief
preliminary scans to locate the general vicinity of otters.
This was followed by intensive scans using spotting scopes to
determine behavioral activity of all otters, to search beyond
binocular range, and to assist in identifying mother/pup
pairs, food items, etc.

General weather conditions and tidal level were noted for
each scan period.   Sightability codes were established for
use during scan sampling in order to identify those scan
samples suitable for statistical comparison.   Sightability
of sea otters on the water's surface was determined for each
search zone during each scan and classified as excellent,
good, fair or poor based on the observer's subjective
evaluation.   Factors affecting sightability included sea

surface condition, glare, and overall lighting conditions
(see Appendix 2). Specific factors influencing sightability
were noted in the weather comments section of each scan
form. Scan samples not deemed suitable for statistical
analysis because of poor sightability conditions were still
used for information on habitat use patterns, feeding
habits, mother/pup interactions, etc.

In some sampling periods scans of one or more zones were
aborted due to unacceptable sighting conditions. These are
referred to as incomplete scans. They provided limited
information on population numbers and distribution but were
not used in analysis of activity budgets.

Information on sea otter population parameters collected
during scan sampling included total numbers, zonal
locations, group sizes, and age/sex categorization when
possible.

We limited the use of the term "group" to aggregations
consisting of three or more otters. This was done largely
because of the frequent difficulty in determining whether
paired animals consisted of a mother with a large dependent
pup or of two older age-class animals. We also considered
aggregations of three or more otters as having the highest
probability of being detected during aerial surveys and felt
that this definition of group size would be of use in
attempting to evaluate the results of simultaneous air and
shore-based surveys. Group defined any aggregation
regardless of the activity in which they were engaged, as
long as all the animals were within ten body lengths
(approximately 10 m) of each other. The term "raft" was used
to define a group of otters when the predominant behavior
was resting.

Otters were aged-classed as either dependent, young of the
year, or as independent individuals, the latter including
all older age classes. We restricted the use of the
classification "dependent pup" to otters which could
definitely be determined as being dependent young of the
year. This determination was based on one or more of the
following criteria: size, behavior of the individual, or the
nature of the interactive behavior between a larger and a
smaller animal. In using the latter two criteria we relied
heavily on the descriptions of pup behavioral development
and mother/pup interactions described by Payne and Jameson
(1984). In cases where it was diffficult to determine
whether the smaller of the two animals in a pair was
definitely a pup we classified both otters as independent
animals. This undoubtedly resulted in conservative counts
as pups approached yearling size, but it also reduced the
likelihood of misclassifying yearlings as pups (Garshelis
and Garshelis 1987).

Miscellaneous sightings of pinnipeds, cetaceans, and river otters (*Lutra canadensis*) were also recorded and will be reported elsewhere.

C) Food Habits

Food habit information was collected by two methods. During scan sampling, food items which were readily identifiable from surface feeding otters were noted as long as it did not violate the procedure for instantaneously scanning individual otter activity states. The second sampling method consisted of monitoring single foraging individuals with spotting scopes (50-80x or 15-60x) for approximately 30 min., or until the otter moved out of visual range or terminated a feeding bout. Food items, in the latter method, were recorded to lowest possible taxon and prey size was estimated as small < 5 cm, medium 5-10 cm, or large > 10 cm). Dive and surface times of both successful and unsuccessful dives were recorded as well as zonal locations.

D) Benthic Survey

During August of 1987, a dive team headed by Rikk Kvitek, University of Washington, collaborated with our ongoing otter surveys to conduct subtidal transects, characterizing benthic communities at several coastal locations, both within and outside of the present otter range. Their methodology and results appear in Appendix 3.

RESULTS

A) Population Numbers and Distribution

Combined air and ground counts of Washington sea otters in
1986 and 1987 appear in Table 1. Highest annual counts,
including all age classes, were 67 individuals in 1986 and
107 in 1987. The discrepancy between years is partly
explained by 1987 natality (20 pups) and the possibility
that some otters at Duk Point were overlooked during 1986
surveys.

Replicate aerial counts were attempted on three consecutive
days, October 19-21, 1987. The first two censuses were
successful but fog blanketed most of the coast on the
third. Total otter counts were 67 individuals on October 19
and 72 on October 20.

With the knowledge that some otters were overlooked during
aerial surveys of the complex nearshore habitat, a "missed"
index was computed based on ground-truthing at the four
shore monitoring sites during seven monthly flights. The
total aerial count for these areas was 215 otters while
ground observers recorded 378 . Thus air counts averaged
56.7% of the ground counts. This missed index was then
applied to aerial counts at areas without shore observers
using the formula $ET = A/0.57$ (ET = estimated total; A = air
count). The resulting estimate of the sea otter population,
based on these computations and assuming that ground
observers counted all otters in their respective areas, was
89 individuals in 1986 and 136 in 1987 (Table 2).

Regional abundance and distribution patterns of otters off
the Washington coast appear in Figure 11. Because of the
variability in monthly aerial counts (top graph), regional
abundance patterns are shown as percent of total counts. The
July 1987 data gap resulted from persistent coastal fog
preventing any systematic survey flight.

In early spring the majority of the otter population resided
at the Cape Alava region (Fig. 11). Their numbers decreased
sharply during late spring as animals moved south, passing
first through the Sand Point region, shown as a May spike,
then ending at Cape Johnson as a summer peak. By late
summer a reverse shift occurred, peaking at the Sand Point
region in August and at the Cape Alava region in September.

During 1986/1987 Washington sea otters ranged from
Destruction Island to just south of Point of the Arches,
some 70 km of coastline (Fig. 5). Based on aerial sightings
we subdivided the area into primary and secondary ranges

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Table 1. Combined air and ground counts of sea otters off the Washington coast, 1986/1987. Numbers include both independent and dependent animals.

Location	June 11			July 15			Aug 20			Dec. 3		Mar 20	
	A[a]	G[b]	T[c]	A	G	T	A	G	T	A	G	A	G
Cape Alava	7	4[d]	4[d]	1	8	9	3	3	5	18	NS	35	NS
Sand Point	11	34[d]	34[d]	1	1	1	0	NS	0	0	NS	6	NS
Cape Johnson	21	NS[e]	21	9	16	16	0	7	7	3	NS	5	NS
Duk Point	1	NS	0	0	NS	0	0	NS	0	0	NS	7	NS
Remaining Areas	7	NS	8	4	NS	4	20	NS	20	19	NS	6	NS
Totals	47	38	67	15	25	30	23	10	32	40	NS	59	NS

1986

a Aerial count

b Ground count

c Total count corrected for duplicate and/or missed sightings by air and ground observers

d Ground counts on June 12 were used and assumed no net movement between the Cape Alava/Sand Point area and the Cape Johnson area between June 11-12.

e No survey

Table 1. (Continued)

Location	1987																
	Apr 17			May 8			June 6			Aug 18			Sept 30			Oct 20	
	A	G	T	A	G	T	A	G	T	A	G	T	A	G	T	A	G
Cape Alava	12	51	51	30	41	41	8	15	15	10	10	10	51	9	53	33	NS
Sand Point	5	4	5	39	NS	39	13	10	13	0	2	2	0	NS	0	4	NS
Cape Johnson	7	8	8	4	8	8	34	43	43	18	NS	18	1	NS	1	3	NS
Duk Point	1	18	18	7	NS	10	5	24	25	5	9	9	9	30	31	13	NS
Remaining Areas	9	NS	9	5	NS	5	6	NS	6	44	NS	44	22	NS	22	19	NS
Totals	34	81	91	85	49	103	66	92	101	77	21	83	83	39	107	72	NS

[a] Aerial count

[b] Ground count

[c] Total count corrected for duplicate and/or missed sightings by air and ground observers.

[d] Ground counts on June 12 were used and assumed no net movement between the Cape Alava/Sand Point area and the Cape Johnson area between June 11-12.

[e] No survey

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Table 2. Estimated population of Washington sea otters based on monthly counts corrected by the missed index ET=A/0.57 (ET=estimated total; A=air count).

	Total Air and Ground Count	Estimated Population
1986		
June	67	89
July	30	33
August	32	47
December	40	70
1987		
March	59	106
April	91	98
May	103	136
June	101	106
August	83	116
September	107	124
October	72	126
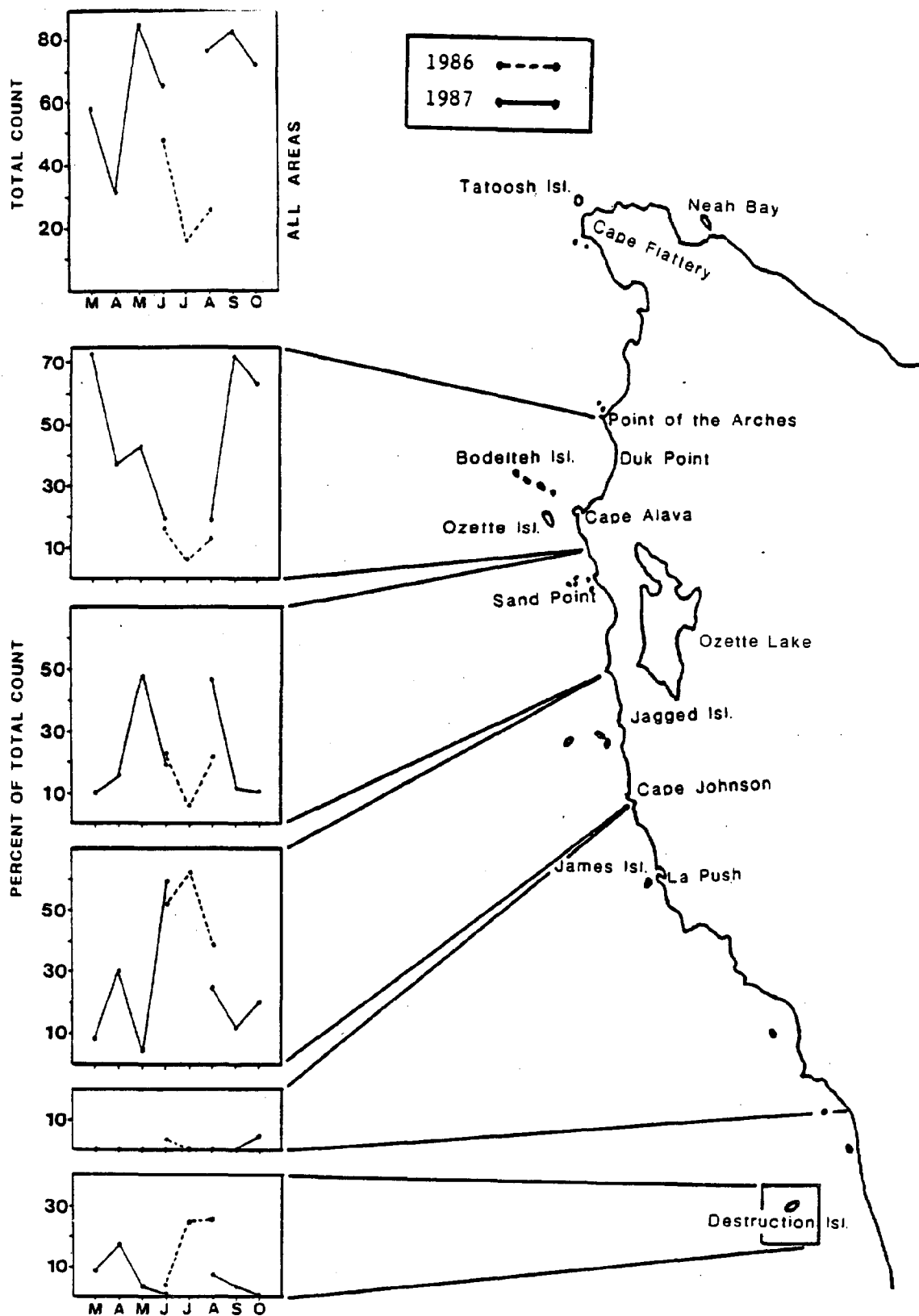
Figure 11. Sea otter distribution patterns from monthly aerial surveys along the Washington coast.

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(Fig. 12). Primary range was defined as areas with frequent
otter sightings ($\bar{x}$ otter sightings per survey flight $\geq$ 3)
while otters were infrequently sighted in secondary ranges
($\bar{x}$ < 3). Otters primarily ranged from Duk Point to Cape
Johnson along the mainland, with an apparent disjunct
subpopulation at Destruction Island.

All otter sightings from Destruction Island to Point of the
Arches were within the 10 fathom isobath (Fig. 5), an area
of 176 km^2(68 mi^2). With the population estimated from 107
to 136, this translates into a density of 0.6-0.8 otters/km^2
(1.5-2.1 otters/mi^2). Although surveys were not conducted
to the 20 fathom isobath (water depths known to be used by
otters elsewhere (Kenyon 1969; Wild and Ames 1974)) this
would increase the total available sea otter habitat in
Washington (within the current range) to some 655 km^2 (253
mi^2).

Weekly abundance patterns of sea otters counted from the
four shore monitoring sites appear in Figures 13-16. The
highest number of otters utilizing Cape Alava occurred in
April (Fig. 13). These high counts gradually decreased
during late spring and early summer. Lowest use of Cape
Alava occurred in June (1987) and July (1986). During
September otters increasingly returned to Cape Alava. The
maximum number recorded at Cape Alava was 43 in 1986 and 53
in 1987.

Otters first appeared in large numbers at Cape Johnson
during late May (Fig. 14), with numbers peaking during June
and July. During August animals began moving away with few
remaining by September. The maximum number utilizing Cape
Johnson was 43 in 1986 and 45 in 1987.

Sand Point was primarily used during late spring and early
summer (Fig. 15), with few otters recorded between July and
September. The maximum number observed at Sand Point was 34
in 1986 and 51 in 1987.

Sea otters were shore-monitored at Duk Point only in 1987
(Fig. 16). From late spring through July maximum numbers
fluctuated around the mid-twenties. The highest count of 36
individuals occurred in September.

Aerial counts of otters at Destruction Island appear in
Table 3. No more than six individuals were recorded per
census in 1986 and 1987. Replicate counts on three
consecutive days (October 19-21, 1987), all with excellent
sighting conditions, showed some variability with counts of
1, 0, and 5, respectively. From 1981 to 1985, seven to ten
otters were sighted around the island (Fig. 4).
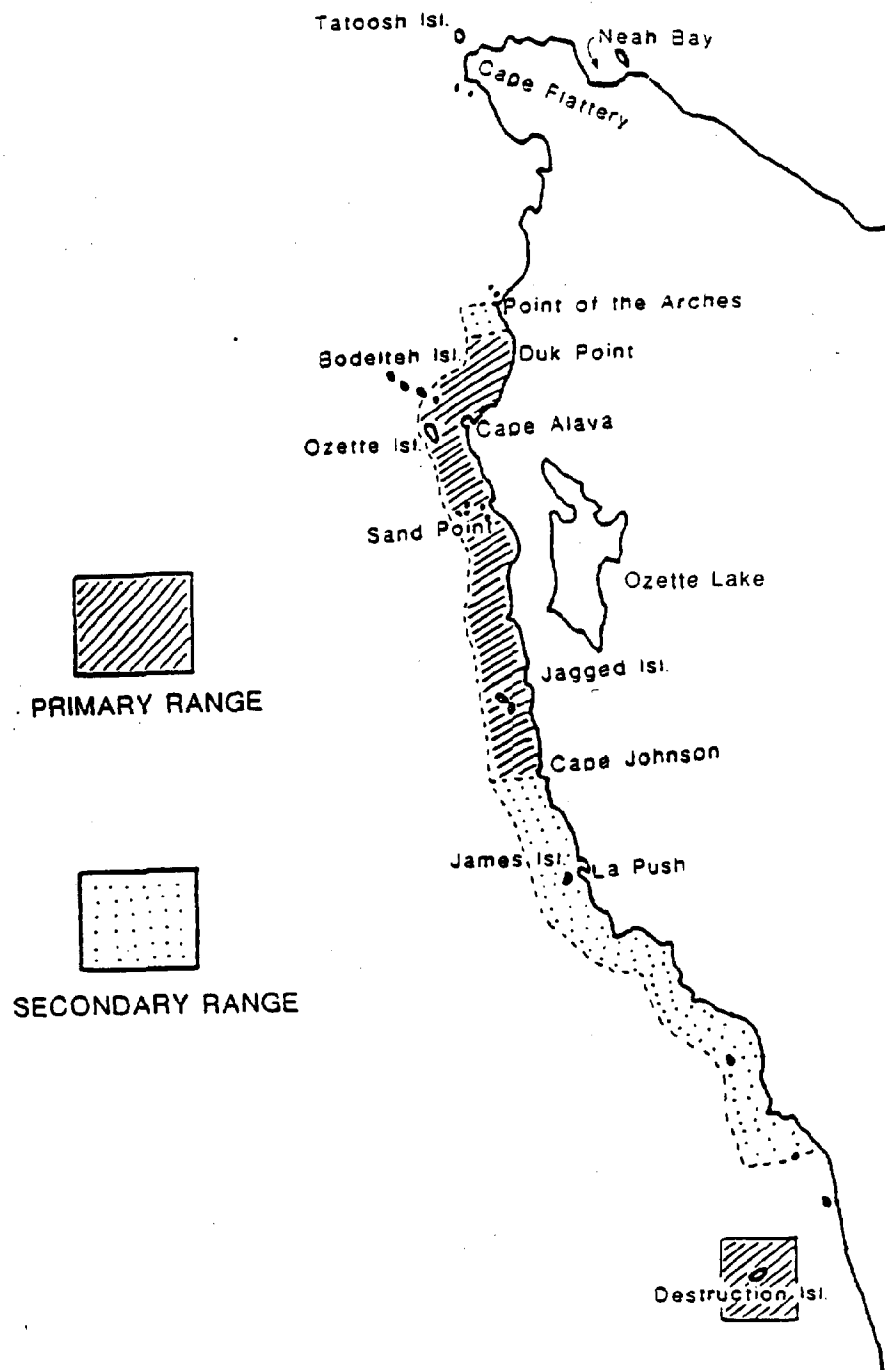
Figure 12. Primary and secondary ranges of sea otters in Washington based on monthly aerial surveys. Mean number of otter sightings per flight for primary range ≥ 3; for secondary range < 3.

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Figure 13. Sea otter abundance at Cape Alava from weekly shore counts, 1986-1987. The mean (crossed line), range (vertical line), and number of observation periods (number above range line) are indicated.
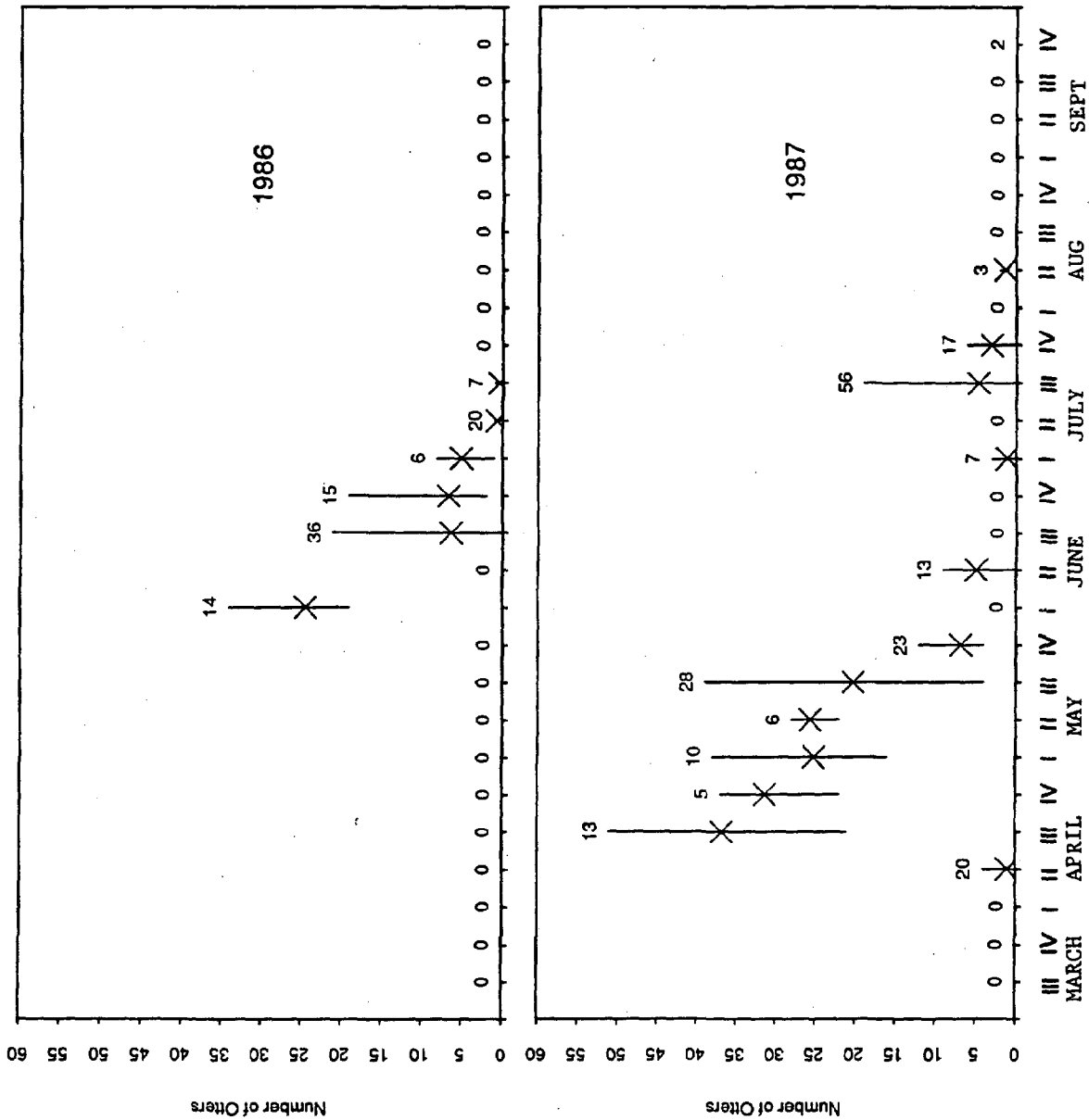
Figure 14. Sea otter abundance at Cape Johnson from weekly shore counts, 1986-1987. The mean (crossed line), range (vertical line), and number of observation periods (number above range line) are indicated.
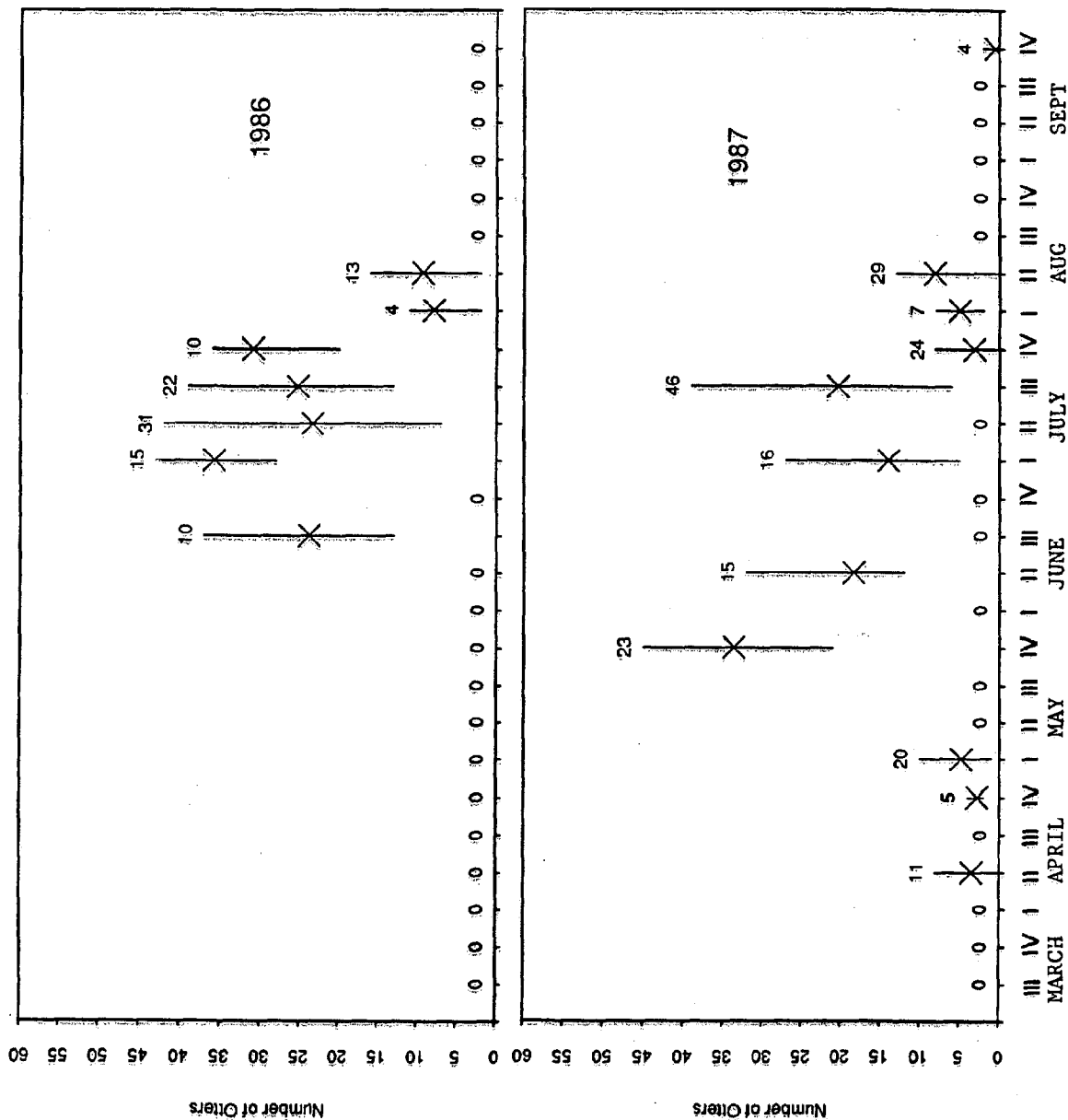
Figure 15. Sea otter abundance at Sand Point from weekly shore counts, 1986-1987. The mean (crossed line), range (vertical line), and number of observation periods (number above range line) are indicated.
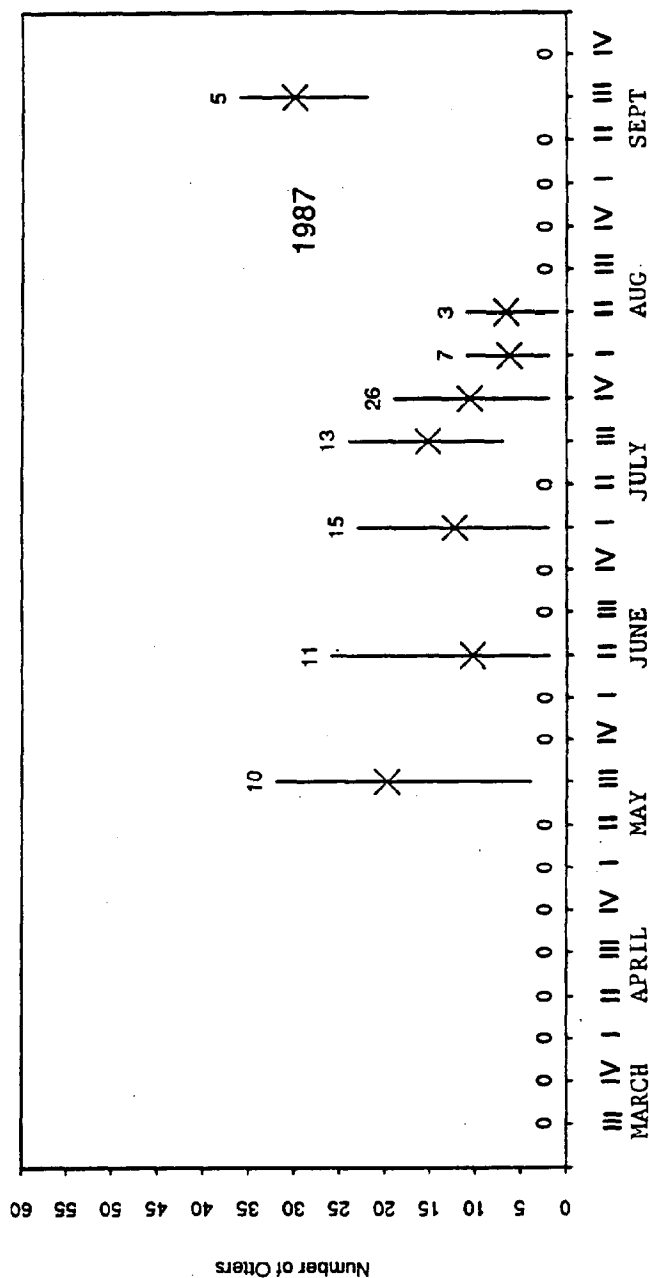
Figure 16.   Sea otter abundance at Duk Point from weekly shore counts, 1987.   The mean (crossed line), range (vertical line), and number of observation periods (number above range line) are indicated.

Table 3. Aerial counts of sea otters at Destruction Island, 1986-1987.

	Number
1986	
May 29	6
June 11	2
July 15	4
Aug. 20	6
Dec. 3	2
1987	
March 20	5
April 17	6
May 8	3
June 3	3
June 6	1
Aug. 18	6
Sept. 10	3
Sept. 17	2
Sept. 30	3
Oct. 19	1
Oct. 20	0
Oct. 21	5

B) Reproduction

Highest pup counts were 16 in 1986 and 20 in 1987 (Table 4).
These numbers were derived primarily from the highest counts
on a single day or two consecutive days though the total for
1987 also included several late-season pups. The pup counts
probably constituted the bulk of pup production. They are
conservative estimates, however, since they were based on
sightings from May through August in 1986, and from April
through September in 1987. No winter pup surveys were
conducted in either year. Although peak pupping in other
areas tend to be limited to a few months a year, pups may be
born in almost any month (Kenyon 1969; Barabash-Nikiforov
1968). Unpublished data for our study area (Figures 3 and
4) show that mother/pup pairs have been sighted in all
months between April and November.

Large viewing distances from the shore sites (averaging 1
km) precluded sexing and age-classing (Garshelis 1984) most
of the otters. Therefore the proportion of adult females in
the population could only be derived from counts of
mother/pup pairs, with a minimum of 16 recorded in 1986 and
20 in 1987.

Highest single day counts of mother/pup pairs at the four
shore sites are shown in Table 4. Although mothers with
dependent pups have occasionally been observed at other
sites in past years (Fig. 4), none were observed outside our
shore monitoring sites and Destruction Island in 1986 or
1987. This may be due partially to aerial surveys being
less effective in detecting pups than shore surveys.

An estimate of the peak pupping period was obtained by
estimating the ages of observed pups and back-dating to the
approximate pupping dates. Early growth and behavioral
development of known aged sea otter pups have been described
by Payne and Jameson (1984) and Davis (1979). Application
of these aging criteria to our observations of pup size and
behavior suggest a peak pupping period from March through
May. In 1987 three late season pups were observed (Table 4)
with pupping dates estimated to be late May/early June for
one and September for the other two. A more accurate
determination of the onset of the pupping period was
unattainable because in both years pups were already present
in the study area before our field work began.

By mid-July most pups had grown in size to the extent that
they were frequently difficult to distinguish from older
age-class animals when seen at a distance. They were also
less closely associated with their mothers by this time, and
prolonged observation was required to establish that a

Table 4. Highest pup counts by area and date along the Washington coast.

	1986	1987
Cape Alava	3 (June 3)	12 (May 10)
Cape Johnson	5[a] (June 11)	9 (June 6)
Sand Point	11 (June 12)	10 (May 22)
Duk Point	NC[b]	0
Destruction Island	0[a]	1[a] (April 17)
Total (all areas)	16 (June 11/12)	17 (May 10) + 1[c] (July 13) + 2[d] (Sept. 30) 20

[a] aerial count

[b] no count

[c] late season pup (estimate age 4-6 weeks)

[d] late season pups (estimated ages <4 weeks)

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mother/pup relationship existed. Because of these problems and the conservative criteria we used in identifying young-of-the-year, our pup counts during late summer were undoubtedly low.

We were unable to determine with any certainty those sites in the study area where pupping occurred. Many of the pups observed initially were already as much as several weeks old and it is possible that they were born at sites other than where we saw them. This possibility is based on observations from other studies indicating that mothers with small pups may change locations frequently (Sandegren et al. 1973), tend to move greater distances than females with older pups (Garshelis and Garshelis 1984), and are capable of moving relatively long distances in short periods of time (up to 2 miles in 45 minutes (Sandegren et al. 1973)).

Our own observations indicated that movements of mother/pup pairs occurred within the study area. In 1986 maximum daily counts of 11 mother/pup pairs were obtained at Sand Point on June 12 and 13 (Table 4). The previous high pup count for that site had been 3 mother/pup pairs observed on June 4. Based on the size and behavior of the pups observed on the 11th and 12th, we concluded that the increase in pup numbers at Sand Point had resulted from a movement of mother/pup pairs into that site and not from pups being born there. During subsequent observation periods no more than 4 mother/pup pairs were seen at Sand Point.

Similarly in 1987, 12 mother/pup pairs were observed at Cape Alava on May 10 (Table 4) and the daily high count was 44 otters (both dependent and independent). But by May 21 only 3 pairs were observed and the high total count was 23. In the same time frame Cape Johnson had 1 mother/pup pair and a daily high count of 7 (May 9) but by June 6, 9 pairs were observed and the daily high count was 45. Apparently some mother/pup pairs and a portion of the total population had shifted from Cape Alava to Cape Johnson.

Fourteen instances of pre-copulatory behavior (Kenyon 1969; Loughlin 1980; Garshelis et al. 1984) were observed during July and August. Adult males typically swam belly-down to rafting groups, nuzzling each individual while apparently checking on their estrus condition. In most cases the males then left the rafts. Two attempted and one apparently successful copulation were observed.

C) Mortality

Mortality information for Washington sea otters is minimal. Initial mortalities following the 1969 transplant were due

largely to hypothermia, a result of transport and handling procedures prior to their release (Kenyon 1970).

Since the transplants, reports of dead sea otters from the outer coast have been rare. This is due in part to relatively few people traveling the rugged and roadless stretches of the coast within the otter's present range.

During our study only two dead sea otters, one adult male and one adult female, were recovered. Cause of death was undetermined in both cases. Necropsy reports appear in Appendix 4.

D) Activity-Time Budgets

Diurnal activity budgets, based on 499 hours of observations, revealed that Washington sea otters spent a relative small proportion of their time feeding, 9.5% in 1986 (Table 5) and 11.2% in 1987 (Table 6). The majority of their daylight hours were passed in a resting state, 62.6% in 1986 and 66.1% in 1987.

Cape Alava otters spent 10.5-11.9% of their daylight hours feeding, 1986 and 1987 respectively (Tables 5 and 6). Zone 2 was the most utilized area for both feeding and resting. At Cape Johnson, the foraging proportion was 8.7 and 10.3%, 1986 and 1987 respectively. Zone 3 was the prefered area for both feeding and resting otters. Sand Point otters spent 8.6 and 11.1% of their diurnal budget feeding, 1986 and 1987 respectively, with Zone 2 the favored feeding and resting area. Duk Point otters allocated 16.1% of their time to feeding in 1987. Their favored foraging area was Zone 3 while the majority of resting occurred in Zone 2b.

E) Activity Patterns

Trends in sea otter activity patterns are illustrated by site, year, hour, and tide level in Figures 17 to 20. Smoothed lines were computed by averaging scatter plots of the respective activities. Overall the feeding and resting patterns for the combined sites showed little hourly variation in 1986 (Fig. 17). The proportion of foraging otters increased slightly during evening hours, most noticeably at Cape Alava. Resting remained near uniform levels throughout the day with a slight increase during evening hours. Otters at Cape Johnson showed an anomalous decrease in resting at midday.

Overall hourly activity patterns in 1987 were also near uniformity (Fig. 18), although individual sites revealed greater variations. At Cape Alava the proportion of resting

Table 5. Diurnal activity budgets of sea otters at three Washington shore sites, 1986.

Shore site	Scan Zone	Percent Time of Activity			No. of Scans	Total No. Otters	Maximum No. Otters/Scan
		Resting	Feeding	Other			
Cape Alava	1	42.9	57.1	0.0	97	7	2
	1B	63.5	9.5	27.0	93	126	11
	2	65.2	8.8	26.0	97	434	33
	2B	58.1	11.6	30.2	92	43	6
	3	57.1	14.3	28.6	95	21	5
	3B	60.4	16.7	22.9	88	48	7
	4	61.3	12.9	25.8	96	31	2
	4B	14.3	14.3	71.4	96	7	2
	Combined Zones	63.0	10.5	26.5	754	717	43
Sand Point	1	78.8	3.0	18.2	97	66	9
	1B	42.9	14.3	42.9	69	7	2
	2	68.9	8.0	23.0	91	499	26
	2B	28.8	24.7	46.6	60	73	15
	3	16.7	50.0	33.3	76	18	4
	3B	0.0	66.7	33.3	58	3	1
	4	50.0	22.7	27.3	98	22	4
	4B	75.0	6.2	18.8	78	16	2
	Combined Zones	63.4	11.1	25.6	98	704	34
Cape Johnson	1	15.8	47.4	36.8	105	19	5
	1B	9.7	61.1	29.2	102	72	10
	2	5.1	19.1	75.7	104	136	20
	2b	33.3	36.4	30.3	104	33	4
	3	72.9	2.8	24.3	102	1949	41
	3b	33.3	38.0	28.7	99	108	12
	4	56.8	15.6	25.7	105	74	11
	4b	25.7	17.8	56.4	102	101	6
	Combined Zones	62.3	8.7	28.9	823	2492	43
Combined Sites	Combined Zones	62.6	9.5	27.9	2204	3913	51

Table 6. Diurnal activity budgets of sea otters at four Washington shore sites, 1987.

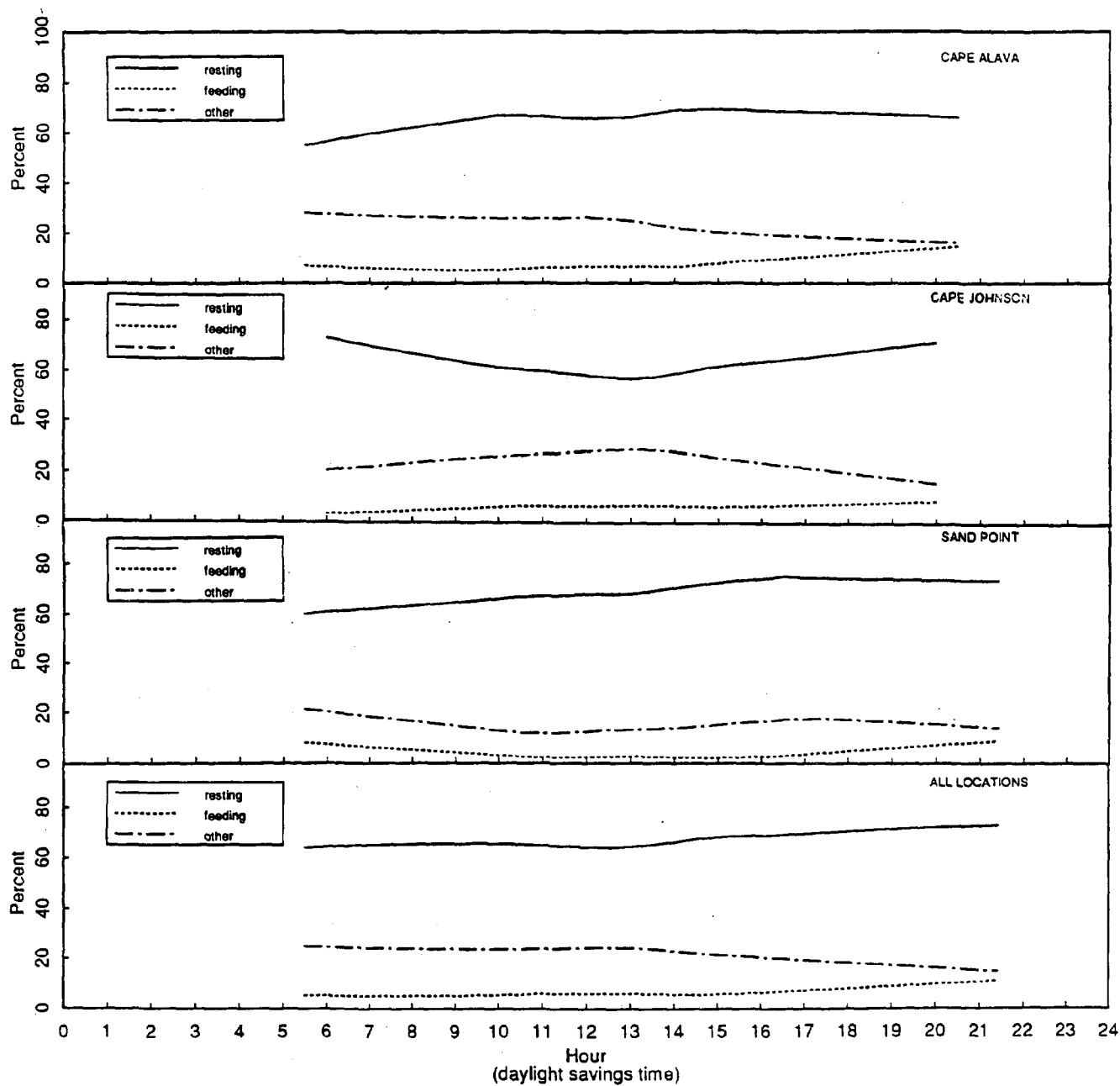| Shore Site	Scan Zone	Percent Time of Activity			No. of Scans	Total No. Otters	Maximum No. Otters/Scan
		Resting	Feeding	Other			
Cape Alava	1	69.5	15.6	14.9	192	154	24
	1B	52.9	13.2	33.9	147	189	12
	2	73.5	8.0	18.5	188	2379	45
	2B	49.4	21.7	28.9	152	83	15
	3	50.0	24.9	25.1	190	366	21
	3B	50.3	19.4	30.4	166	191	9
	4	57.7	24.7	17.5	191	97	8
	4B	51.3	14.9	33.8	171	74	11
	Combined Zones	67.1	11.9	21.1	1397	3533	53
Sand Point	1	72.6	5.8	21.6	194	190	29
	1B	37.9	19.0	43.1	158	58	6
	2	76.3	7.0	16.7	188	1571	48
	2B	54.5	25.0	20.5	147	44	4
	3	29.8	33.3	36.8	185	57	5
	3B	58.1	9.3	32.6	144	43	7
	4	55.2	17.2	27.6	189	29	2
	4B	66.7	9.5	23.8	159	21	2
	Combined Zones	72.2	8.6	19.2	1364	2013	52
Cape Johnson	1	24.7	35.1	40.3	194	77	5
	1B	25.0	40.0	35.0	179	20	4
	2	12.9	37.1	50.0	194	62	8
	2B	25.0	0.0	75.0	183	4	2
	3	73.9	4.4	21.7	196	1968	44
	3B	3.8	53.8	42.3	187	26	13
	4	47.1	26.0	26.8	196	246	20
	4B	33.9	21.3	44.8	180	230	10
	Combined Zones	63.9	10.3	25.8	1509	2633	45
Duk Point	1	0.0	53.8	46.1	78	13	3
	1B	70.0	20.0	10.0	64	10	2
	2	41.2	29.4	29.4	81	136	17
	2B	75.2	0.8	24.0	62	359	26
	3	61.0	15.5	23.5	81	387	19
	3B	57.6	4.0	38.4	65	99	17
	4	18.0	54.0	28.0	81	100	13
	4B	26.1	47.8	26.1	66	23	6
	Combined Zones	57.7	16.1	26.3	578	1127	34
Combined Sites	Combined Zones	66.1	11.2	22.6	4848	9306	72

Figure 17. Sea otter activity patterns by hour at three Washington shore sites, 1986.
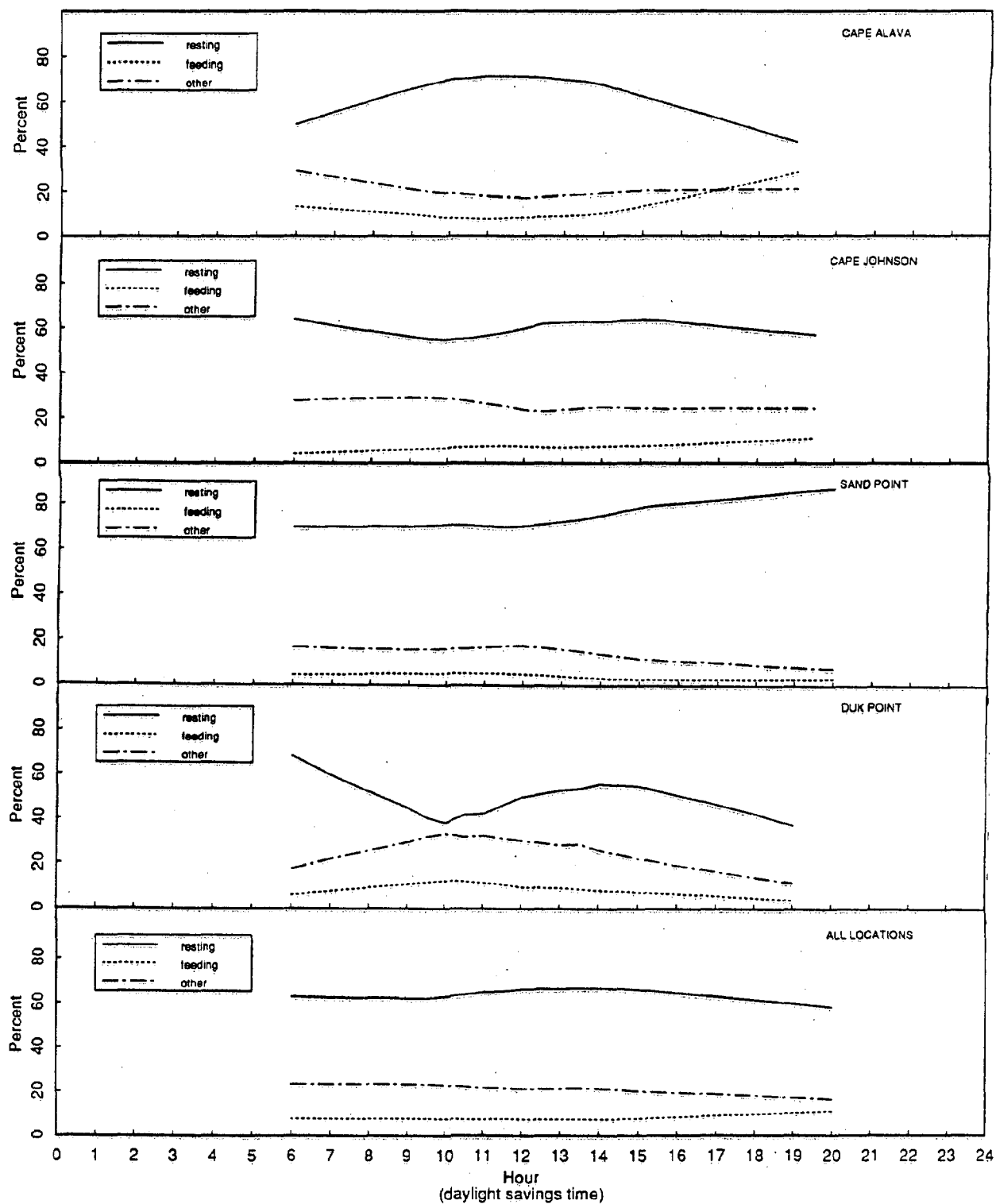
Figure 18. Sea otter activity patterns by hour at four Washington shore sites, 1987.
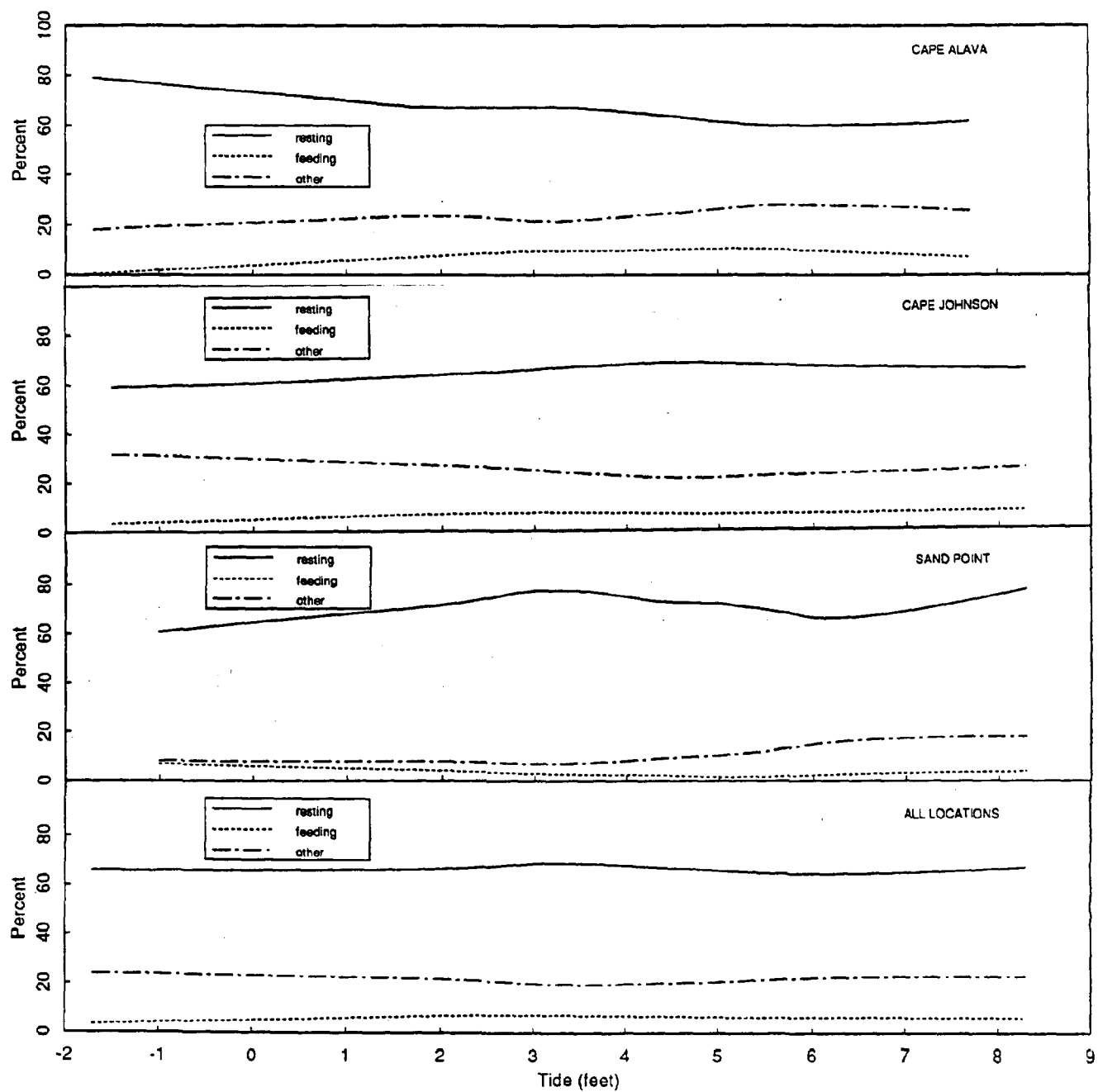
40

Figure 19. Sea otter activity patterns by tide level at three Washington shore sites, 1986.
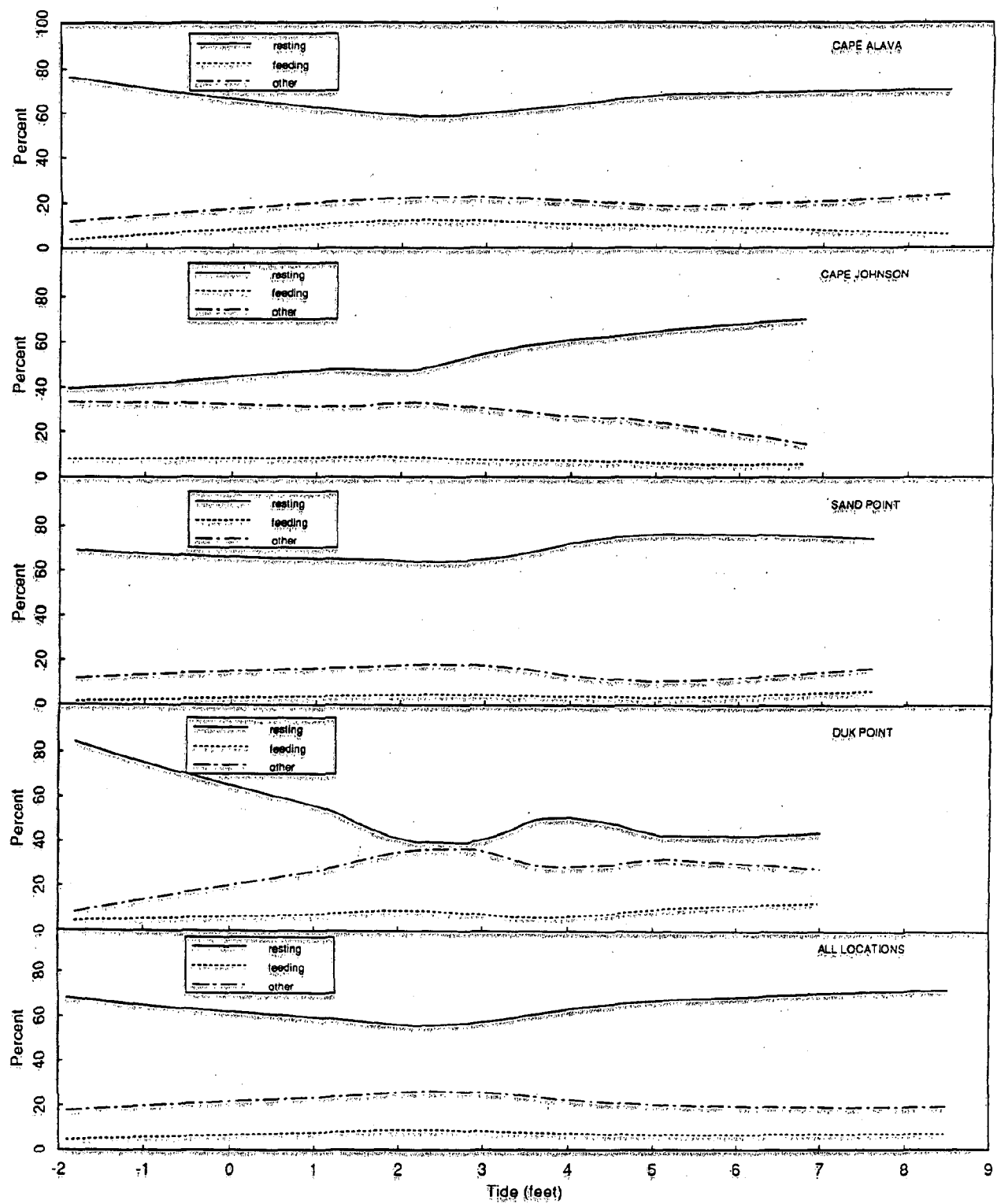
Figure 20. Sea otter activity patterns by tide level at four Washington shore sites, 1987.

otters showed a substantial midday peak, while feeding rose
sharply during evening hours, far greater than in 1986. Duk
Point otters had anomalous patterns with a dramatic drop in
resting during midmorning mirrored by increased feeding and
other activities.

There were no consistent trends in overall otter activity
related to tidal influences in 1986 (Fig. 19). At Cape
Alava the proportion of feeding otters increased at higher
tide levels and was near zero at minus tides while the
resting proportion showed a decreasing trend from minus to
plus tides. Cape Johnson otters maintained fairly
consistent levels of activities across all tides. Resting
levels increased at Sand Point from minus to +3 tides,
subsided, then increased between +6 to +7.

Overall activity patterns in 1987 also showed few tidal
related trends, except for resting levels which slowly
decreased from minus to +2 tides and then slowly increased
(Fig.20). The feeding proportion of Cape Alava otters
increased slowly from minus to +2 tides, mirrored by a
decrease in resting. Resting levels of Cape Johnson otters
rose steadily, peaking at approximately +7 tide. Conversely
Duk Point otters had their highest resting levels at minus
tides.

In summary, while site-specific activity patterns related to
time of day and tide level were detectable within individual
years, the patterns observed at each site were not
consistent between years. Overall activity patterns for
each year also showed no consistent trends with time of day
and tide level. These findings are similar to those reported
in California (Hall and Schaller 1964; Loughlin 1977; Ribic
1982).

F) Groups

Sea otters were frequently seen in groups of three or more
individuals at the four shore monitoring sites (Table 7).
For all sites combined, otters were in groups between 59.8-
61.3% of the total sightings. Maximum groups sizes ranged
from 20-44 individuals. Highest group numbers occurred in
early spring at Cape Alava, early summer at Cape Johnson,
and early to mid spring at Sand Point, closely paralleling
the weekly abundance patterns at the respective sites (Fig.
14-16).

Groups containing mother/pup pairs were sighted most
frequenty at Sand Point, while none were seen at Duk Point
(Table 7). The frequency of mother/pup pairs within groups
was conservative since large viewing distances (averaging 1
km) often prevented distinctions between older pups

Table 7. Group size and frequency information on Washington sea otters.

	1986					1987				
	Cape Alava	Sand Point	Cape Johnson	Duk Point	Combined Sites	Cape Alava	Sand Point	Cape Johnson	Duk Point	Combined Sites
Frequency of Group Sightings from Total Counts	42.5%	43.4%	71.9%	NC[a]	61.3%	55.3%	55.6%	68.6%	61.3%	59.8%
Maximum Group Sizes	37	20	40	NC	---	40	44	40	35	---
Frequency of Mother/Pup Pairs Sighted Within Groups	24%	98%	46%	NC	51%	52%	68%	47%	0%	48%

a = no count

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associated with mothers from two independent individuals.
The overall frequency of mother/pup pairs seen within groups
averaged 51% in 1986 and 48% in 1987 (1987's average would
be 54% if Duk Point was excluded).

The presence of mother/pup pairs within groups at Cape
Alava, Sand Point, and Cape Johnson (Table 7), by definition
makes them "female areas" (Kenyon 1969; Schneider 1978;
Garshelis et al. 1984). Although no pups were sighted at
Duk Point this does not necessarily distinguish it as a
"male area." The greater viewing distances at Duk Point
(Fig. 10) compared to the other three shore sites (Figures
7-9) could partially account for the absence of pup
sightings. These distances also precluded sexing any
individuals within the Duk Point groups.

Group numbers were examined for hour and tide related
influences. Smoothed lines were computed by averaging
scatter plots of group numbers to hour (Fig. 21) and tide
level (Fig. 22). Group numbers showed no consistent trends
for either variable.

G) Haulout Behavior

Observations of otters hauling out on offshore rocks at Cape
Alava, Cape Johnson, and Sand Point were not uncommon.
Figure 23 plots hauling frequency to hour while Figure 24
shows the relationship to tide level. These totals do not
include cases where otters were observed to abandon their
haulout site and then rehaul on the same or different rock.
Hauled-out otters were difficult to detect from shore sites
and some may have been overlooked. These sightings
therefore represent conservative numbers.

The majority of hauling occurred during morning hours (Fig.
23) and at minus tides (Fig. 24). The correlation to low
tide was apparently related to otter preferences for kelp
covered rocks which only became exposed during lower tides.
Similar preferences have been reported in California (Faurot
1985) and Alaska (Murie 1940). Only two instances of otters
hauled on bare rock were noted despite the availability of
such rocks at all tide levels.

Most hauling incidents involved single animals although
groups as large as ten otters were observed hauled together
on rare occasions. Hauled otters primarily rested, although
some groomed and interacted. Interactions occasionally led
to one or more otters abandoning sites, especially when
small rocks were involved. In some cases this resulted in
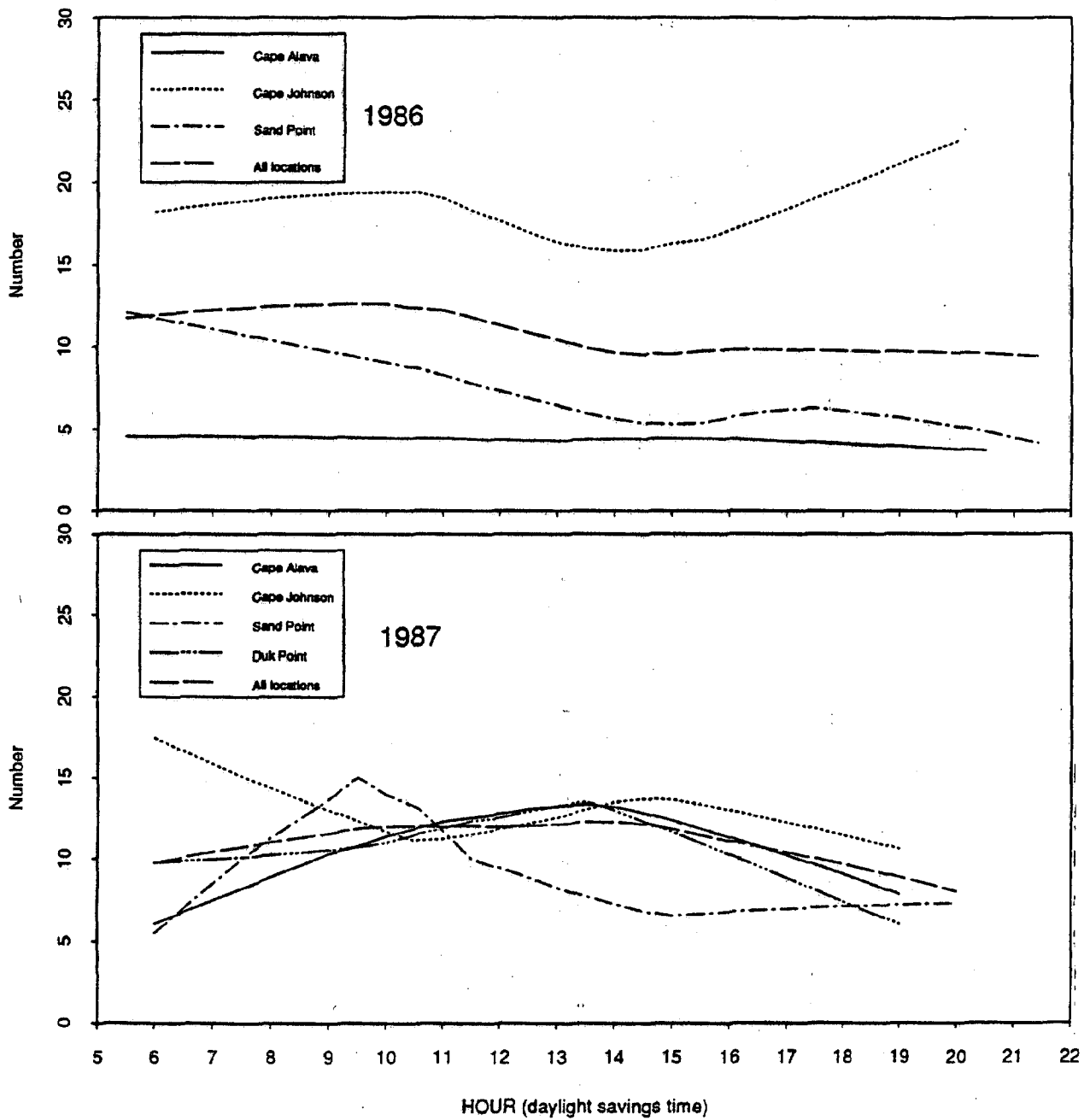rehauling on another rock.

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Figure 21. Sea otter group numbers by hour from Washington shore sites.
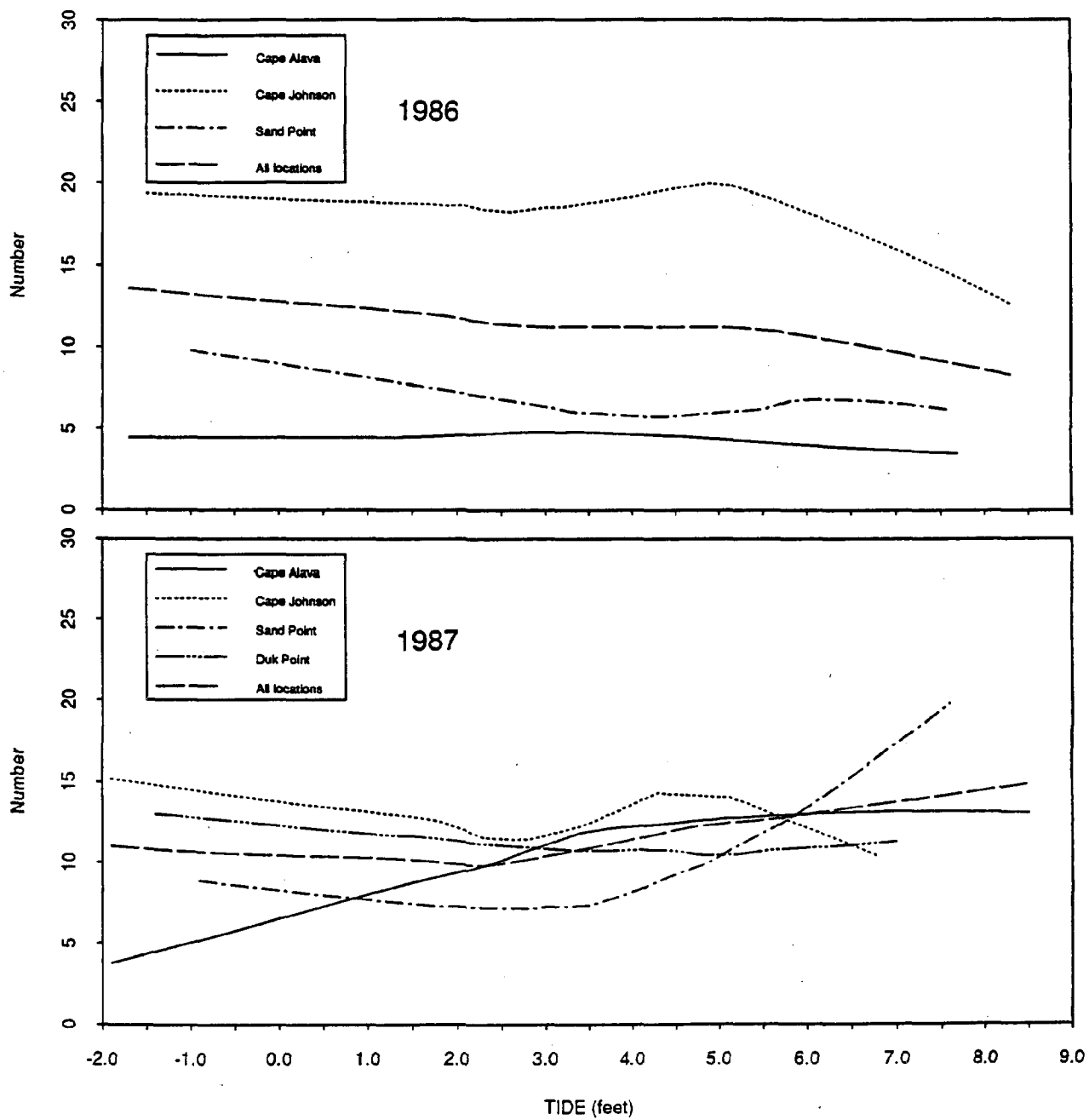
Figure 22. Sea otter group numbers by tide level from Washington shore sites.
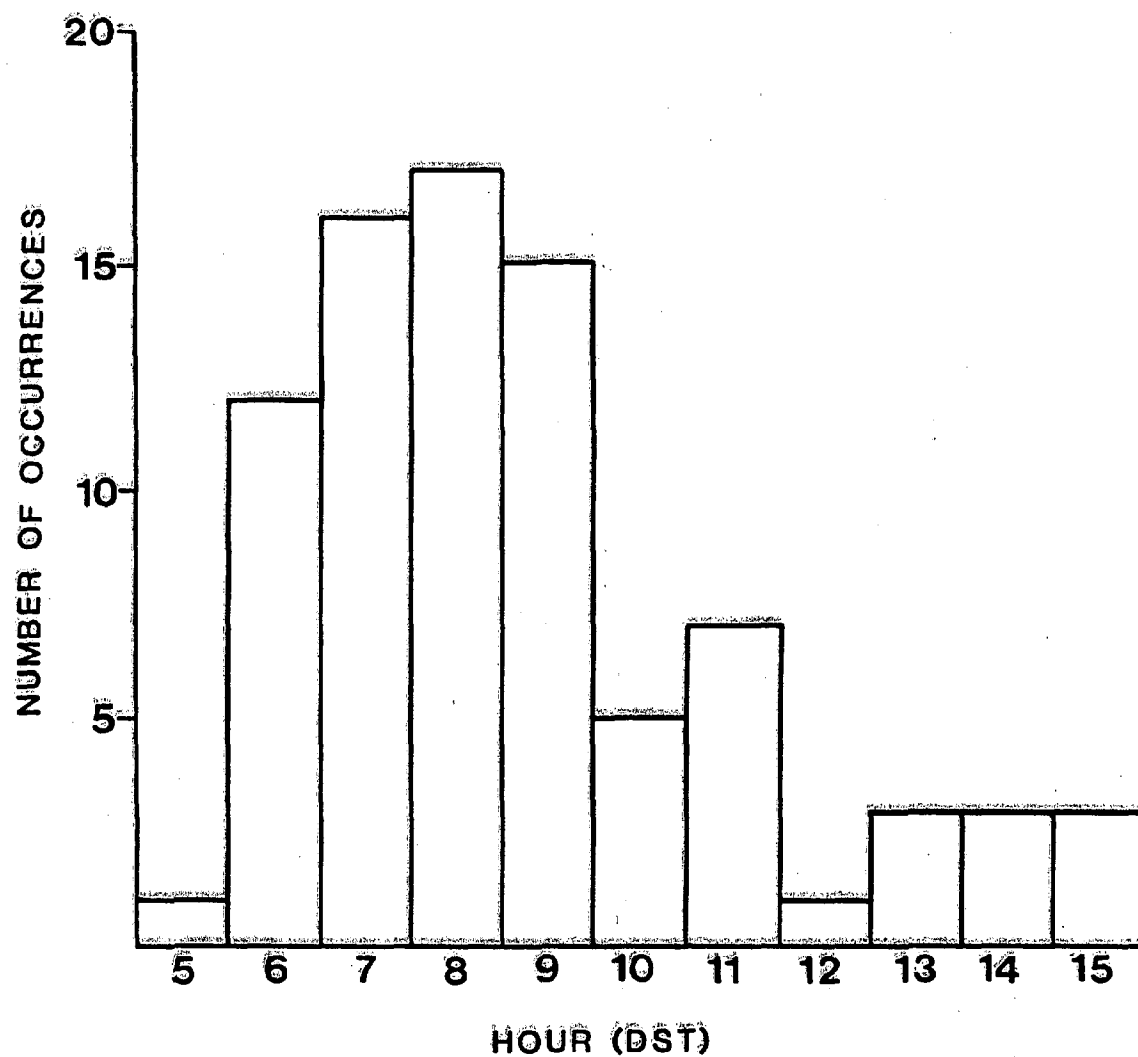
Figure 23. Frequency of sea otter haulout patterns by hour.
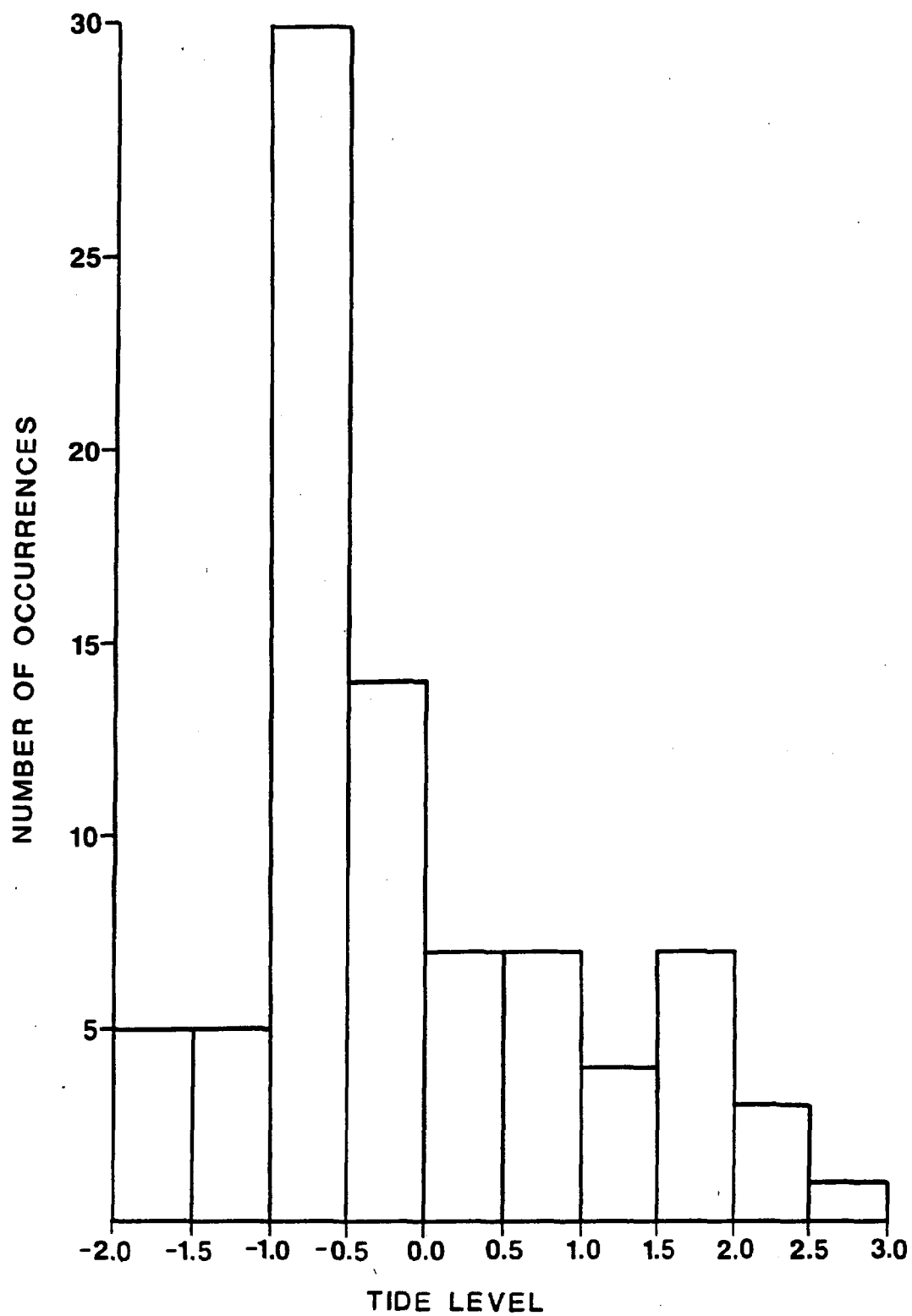
Figure 24. Frequency of sea otter haulout patterns by tide level.

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Hauling apparently involved all age classes. On June 25, 1986, a small dependent pup (estimated age less than 8 weeks) spent several minutes struggling to climb a rock at Sand Point in an attempt to rejoin its mother. The pup was eventually successful but abandoned the rock minutes later when the mother reentered the water. Females with small dependent pups were also observed hauled out at Cape Alava in 1987.

Large numbers of harbor seals (*Phoca vitulina*) also inhabited most of the areas occupied by sea otters. Over 450 were observed at Cape Alava and some 200 at Cape Johnson. The range of haulout sites utilized by harbor seals extended further inshore than those chosen by sea otters with the latter seldom hauling-out less than 200 m. from shore. Despite the abundance of harbor seals in the study area, interspecific sharing of haulout sites was only noted on two occasions, both at Cape Alava. One observation involved 5 sea otters (2 mother/pup pairs plus a single independent animal) sharing a haulout site with 7 harbor seals. The minimum interspecific distance in this case was about 2 m. The second incident involved 1 sea otter, 1 harbor seal and 1 California sea lion (*Zalophus californianus*) on the same haulout site with a minimum interspecific distance of about 6 m. No detectable interspecific behavioral interactions were observed. Neither did we observe any cases of one species displacing another at a haulout site. Sharing of haulout sites by harbor seals and sea otters has also observed in California by Faurot (1985).

H) Food Habits

A total of 9 prey species were identified in the diet of Washington sea otters from scan and focal animal sampling (Tables 8 and 9). Food habit information derived from scan sampling (Table 8) was limited due to large viewing distances, averaging 1 km., curtailing identification of most prey species during the nearly instantaneous scan of individual otters. Unidentified food items were not recorded during scans. Octopus was the most frequently recorded prey for the combined sites, followed by clams and crabs. However larger items, such as octopus, were more readily recognizeable and may be overrepresented in these scan results.

Octopus and crabs were the most common prey observed at Cape Alava (Table 8). Cape Johnson otters showed greater foraging diversity with major prey ranked as octopus, clams, chitons, and crabs. Octopus and sea urchins predominated at Sand Point and clams at Duk Point.

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Table 8. Frequency of occurrence of prey in the diet of Washington sea otters identified during scan sampling.

Prey Item	Cape Alava	Cape Johnson	Sand Point	Duk Point	Combined Areas
Octopus (Octopus sp.)	48%	29%	50%	17%	37%
Littleneck clam (Protothaca sp.)	13	22		33	13
Clam		5		50	10
Gumboot chiton (Cryptochiton stelleri)	9	17			11
Crab (Cancer sp.)	26	17	8		17
Kelp crab (Pugettia sp.)		2			1
Purple sea urchin (Strongylocentrotus purpuratus)	4		8		2
Red sea urchin (S. franciscanus)		2	8		2
Sea urchin (S. sp.)		2	25		5
Sea cucumber (Cucumaria miniata)		2			1
Sample size	23	41	12	6	82

Table 9. Frequency of occurence and estimated size of prey in the diet of Washington sea otters identified during focal animal sampling.

	Estimated[a] Size	Cape Alava		Cape Johnson		Combined Areas	
		Percent[b] Occurrence	Percent Total No. Items	Percent[b] Occurrence	Percent Total No. Items	Percent[b] Occurrence	Percent Total No. Items
Octopus (Octopus sp.)	L	16.7	1.4	14.3	0.7	15.8	1.1
Littleneck clam (Protothaca sp.)	M	8.3	0.7	42.9	48.1	21.1	24.1
	L		0		0.7		0.4
Clam	S	33.3	3.6	42.9	1.5	36.8	2.6
	M		1.4		0.7		1.1
	L		1.4		0		0.7
Gumboot chiton (Cryptochiton stelleri)	M	16.7	0	14.3	37.0	15.8	1.8
	L		1.4		6.7		4.0
Crab (Cancer sp.)	S	16.7	0.7	28.6	0	21.1	0.7
	M				1.5		1.1
	L		0.7		0		0.7
Kelp crab (Pugettia sp.)	S	25	0.7	14.3	0	21.1	0.7
	M		4.3		0.7		25.5
	L		2.2		0		1.1
Red sea urchin (Strongylocentrotus franciscanus)	L	16.7	2.2	14.3	0.7	15.8	1.5
Sea cucumber (Cucumaria miniata)	M	33.3	6.5	42.9	37.0	36.8	5.1
	L		1.4		0		0.7
Unidentified items	S	91.7	49.6	85.7	25.9	89.5	38.0
	M		19.4		5.2		12.4
	L		1.4		0		0.7
Sample size		12	139	7	135	19	274

a Sizes: S < 5 cm; M 5-10 cm; L > 10 cm
b Size categories combined

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A more representative sample of sea otter food habits,
albeit small, came from focal animal monitoring sessions
(Table 9). Of the 12 animals monitored at Cape Alava, their
major prey consisted of clams, sea cucumbers, and crabs.
However most of them (92%) had unidentified prey in their
diets, accounting for 70.4% of the number of items consumed.

The diet of the seven otters monitored at Cape Johnson
consisted mostly of clams, sea cucumbers, chitons, and crabs
(Table 9). Although the majority of these otters surfaced
with unidentified prey, it accounted for only 31.1% of the
135 items consumed.

Estimated size categories of prey items recorded during
monitoring sessions are shown in Table 10. Most Cape Alava
otters consumed small prey, < 5 cm, while otters at Cape
Johnson foraged predominately on medium sized items, 5-10
cm. The table also clearly illustrates that the majority of
unidentified prey were small items.

Time duration of foraging dives and surface consumption
rates of major prey items appear in Table 11. Octopus,
although rarely encountered during food habit monitoring
sessions, required the longest amount of time for otters to
consume of all prey items, averaging almost 40 min. for two
instances at Cape Alava. The one recorded case at Cape
Johnson was less than a minute of surface time due to the
otter discarding most of the prey. Dive/search times for
octopus were unavailable. Captured octopus were huge,
roughly 1/2 - 2/3 the dimensions of the otter's abdominal
area. Their large size in conjunction with the extensive
time required to consume on the surface account for their
overrepresentation in scan samples versus the infrequency of
occurrence in focal animal monitoring.

If dive/search times are equivical to encounter rates for
individual prey species density, then Table 11 should reveal
something of prey abundance. Mean dive times of otters
foraging on gumboot chitons (*Cryptochiton stelleri*) were
69.5 sec. at Cape Alava and 50.5 sec. at Cape Johnson,
possible indicating a greater chiton abundance at Cape
Johnson. The reverse held for rock crabs (*Cancer* spp.).

Although mean dive times for red sea urchins
(*Strongylocentrotus franciscanus*) were short (Table 11),
this probably related to their opportunistic discovery while
otters foraged on other prey immediately before and after,
and is not an indication of abundance. Otters took nearly
three minutes to consume these urchins.

Sea cucumbers (*Cucumaria miniata*) were apparently more
abundant at Cape Alava than Cape Johnson as indicated by the

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Table 10. Estimated size categories of Washington sea otter prey recorded during focal animal monitoring (N=number of prey items).

		S [<5cm]	PERCENT M [5-10cm]	L [>10cm]
CAPE ALAVA				
	Identified Prey Species (41)	17.1	46.3	36.6
	Unidentified Prey (98)	70.4	27.6	2.0
	Combined (139)	54.7	33.1	12.2
CAPE JOHNSON				
	Identified Prey Species (93)	2.1	84.9	12.9
	Unidentified Prey (42)	83.3	16.7	0
	Combined (135)	27.4	64.4	8.1
COMBINED AREAS				
	Identified Prey Species (134)	6.7	73.1	20.1
	Unidentified Prey (140)	74.3	24.3	10.7
	Combined (274)	41.2	48.2	10.6

Table 11. Mean dive and surface times (seconds) of sea otters foraging on different prey type (SD=standard deviation) and N=number of samples.

	CAPE ALAVA		CAPE JOHNSON		COMBINED	
	Dive(SD)	Surface(SD)	Dive(SD)	Surface(SD)	Dive(SD)	Surface(SD)
Octopus (Octopus sp.) N=	--- 0	2370 (990) 2	--- 0	56 (0) 1	--- 0	1598.7 (1357.7) 3
Littleneck clam (Protothaca sp.) N=	55 (0) 1	53 (0) 1	76.5 (23.1) 40	49 (30.0) 40	76 (23.1) 41	49.1 (29.6) 41
Clam N=	73.7 (14.8) 6	62.2 (52.6) 6	161.3 (31.3) 3	28.3 (4.2) 3	102.9 (46.4) 9	50.9 (42.4) 9
Gumboot chiton (Cryptochiton stelleri) N=	69.5 (33.2) 2	34 (11.3) 2	50.5 (18.2) 10	35.7 (16.7) 10	53.7 (20.4) 12	35.4 (15.6) 12
Crab (Cancer sp.) N=	51.7 (13.3) 3	26.7 (8.4) 3	86.5 (28.5) 2	102.5 (61.5) 2	65.6 (26.2) 5	57 (54.0) 5
Kelp crab (Pugettia sp.) N=	25.8 (18) 10	48.2 (23.0) 9	--- 0	--- 0	25.8 (18) 10	48.2 (23.0) 9
Red sea urchin (Strongylocentrotus franciscanus) N=	33 (9.9) 2	158 (103) 2	41 (0) 1	196 (0) 1	35.7 (6.8) 3	110.7 (86.0) 3
Sea cucumber (Cucumaria miniata) N=	48 (13.4) 9	28.7 (9.5) 9	66.3 (26.6) 4	63.8 (34.7) 4	53.6 (20.0) 13	39.5 (26.2) 13

mean search times, 48 sec. and 66.3 sec. respectively (Table 11).

Foraging dive times and success rates of sea otters by sex are shown in Table 12. Overall mean dive times for females were less than males. Females with pups had even shorter dive times. The majority of foraging dives were successful for all otters, averaging 88.5% at Cape Alava and 89.4% at Cape Johnson.

One adult female at Cape Alava showed an unusual dive pattern while foraging on kelp crabs (*Pugettia* spp.). She performed short shallow dives ($\bar{x}$ = 25.8 sec.), with her hindquarters intermittently bobbing up into the surface canopy of *Macrocystis*, before finally surfacing with a kelp crab.

Individual otters preyed mostly on one or two species during their observed foraging bouts (Table 13). However this may overestimate the individual selectivity since the majority of otters were observed with some unidentified food items (Tables 8 and 9).

Tool use by Washington sea otters was rare. Only 1.5% of the successful dives at Cape Alava revealed use of a surface tool. At Cape Johnson tool use occurred in 10.9% of the dives. Most of the latter were from an individual cracking clams over a rock anvil on his chest.

I) Benthic Survey

Results of the benthic survey appear in Appendix 3.

Table 12. Mean dive times (seconds) and foraging success rates of sea otters by sex.

Sex	# Individual Otters	# Dives Observed	X̄ Dive Times(SD)	Success Rate
Cape Alava				
M	2	15	74.3(41.6)	78.6%
F	3	34	40.1(22.8)	87.1
F w/pup	2	52	44.0(16.4)	91.8
Sex?	5	54	59.5(18.5)	88.9
Cape Johnson				
M	2	39	66.5(20.6)	94.6%
F	1	14	95.1(13.5)	100
F w/pup	1	19	56.3(20.1)	78.9
Sex?	3	44	102.2(42.9)	86.4
Combined Areas				
M	4	54	68.6(28.3)	90.2%
F	4	48	56.8(32.4)	90.9
F w/pup	3	71	47.3(18.3)	88.2
Sex?	8	98	80.6(39.2)	87.8

Table 13.   Number of prey species per individual otter foraging bout.

	CAPE ALAVA	CAPE JOHNSON
Percent of otters foraging on:		
1 prey species	36.4%	42.9%
2 prey species	27.3	42.9
3 prey species	9.1	14.3
4 prey species	9.1	0

DISCUSSION

A) Population Growth and Status

Growth rates of the post-transplant Washington sea otter
population were difficult to reconstruct since no systematic
survey data existed before 1977, and only limited information
was available between 1977 and 1985 (Fig. 3). In Figure 25 we
present several estimated growth rate scenarios for the post-
transplant period, depicted as minimum and maximum rates.
The minimum growth rates were derived using an initial
population size of 43 animals (the sum of the 1969 and 1970
transplants minus known mortalities) and end points of our
1987 high count (107) and 1987 population estimate (136).
Average annual population growth rates derived from these
data are 5.5% and 7.0% respectively.

Because of the likelihood that the population initially
decreased following the transplants, as suggested by the low
population counts obtained in 1977 (Jameson et al. 1982), we
present a second set of population growth rate estimates
which depict a more rapid increase of the population
following the apparent decline. These estimates use a
conservative starting point of 19 animals counted in 1977
(Jameson et al. 1982) and the same population end points of
107 and 136 derived from our 1987 data. The population
growth rates based on these numbers are 18.9% and 21.7%
respectively.

Although the otter counts used to calculate these population
growth rates are not directly comparable, due to different
survey methodologies, they do allow creation of upper and
lower bounded estimates, with the actual growth rate probably
falling somewhere in between (Fig. 23). In comparison, otter
populations in areas below equilibrium densities have been
shown to increase at 10-16% per year (Kenyon 1969; Estes
1981).

Both Jameson's and Jeffries' data for the period from 1977
to 1985 (Fig. 3) are suggestive of a fairly rapid popula-
tion growth rate analogous to that of newly transplanted
otter populations in other areas (Kenyon 1969; Estes 1981).
We believe it is likely that the Washington population did
in fact suffer a decline during the initial post-transplant
period as did the Oregon transplant which eventually failed
(Jameson et al. 1986).

Based on the results of boat surveys between 1977 and 1985,
Jameson et al. (1986) estimated the Washington population
grew at an average annual rate of 16.5%. This estimate may
be high since their 1985 survey may have double-counted a

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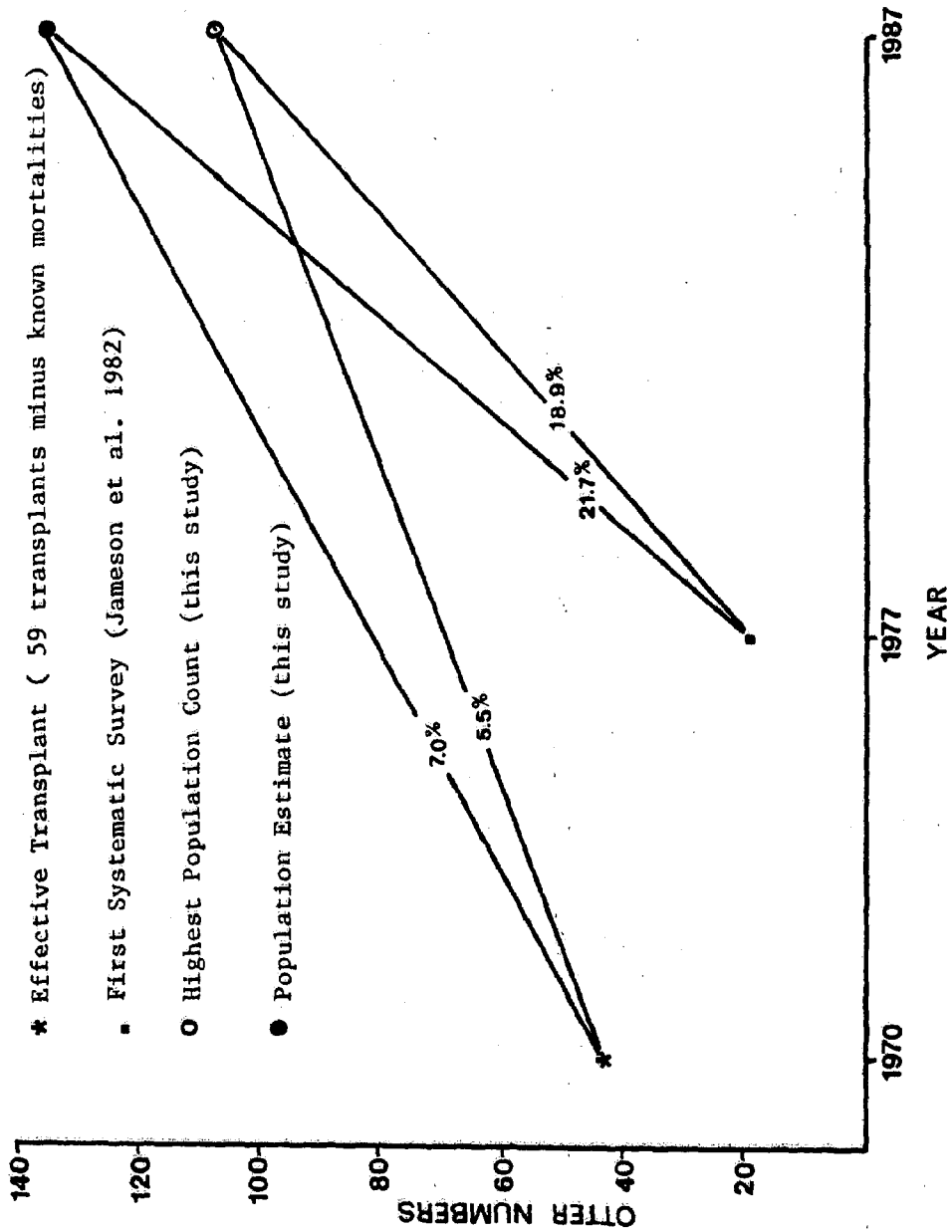
Figure 25. Estimated growth rates for the Washington sea otter population after the 1969/1970 transplants to the 1987 surveys.

* Effective Transplant (59 transplants minus known mortalities)
■ First Systematic Survey (Jameson et al. 1982)
O Highest Population Count (this study)
● Population Estimate (this study)

YEAR

OTTER NUMBERS

1970   1977   1987

18.9%

21.7%

7.0%

5.5%

portion of the population. However it still falls within our maximum and minimum rate estimates.

There are several potential biases affecting reliability of sea otter sightings during surveys. Otter activity levels are a factor since individuals resting on the water surface are more readily visible than those actively foraging/diving (Garshelis 1983; Estes and Jameson 1988). Determining peak resting periods of otter populations should therefore play a role in scheduling surveys or interpreting results (Estes 1977; Garshelis 1983; Garshelis and Garshelis 1984). Our data, however, revealed no resting peaks in relation to time of day or tide level (Fig. 17-20). In fact the otters showed rather consistent resting levels throughout the day.

Another sighting factor is whether otters are in groups or alone. Since large rafting groups are obviously easier to detect than single otters, prediction of grouping behavior should be a component in scheduling or interpreting surveys. Our data, however, showed no consistent trend in group numbers to hour of day or tide level (Fig. 21-22).

Although the two preceeding factors did not appreciably affect sighting reliability of our surveys, one potential bias was otter haulout behavior. Sea otters hauled-out on rocks were extremely difficult to see, particularly by air observers. Since most hauling activity of Washington otters occurred during during minus tides (Fig. 24), future surveys should avoid these conditions.

During our 1986-1987 surveys, Washington sea otters were distributed from Destruction Island to Point of the Arches, primarily ranging between Duk Point and Cape Johnson with a small aggregation at Destruction Island (Fig. 12). Prior to the initiation of our survey, between September and October of 1985, a single male otter was recorded at Neah Bay on six occasions (Calambokidas et al. 1987) but never subsequently resighted. Presumably the individual had returned to the primary range south of Cape Flattery. This is not an uncommon trait of male otters to range beyond the periphery of major otter population centers in California (Riedman 1987) and Alaska (Garshelis 1983). If the main population range continues to expand northwards, they could eventually meet another otter population, transplanted to Vancouver Island, British Columbia, between 1969-1972 (Morris et al. 1981; Fig. 1). At present these otters, numbering some 345 animals, are distributed along the west coast of Vancouver Island, concentrated between Brooks Peninsula and Nootka Sound (MacAskie 1987). Some individuals of the Vancouver population range as far south as Barkley Sound, approximately 85 km north of Point of the Arches. The Strait of Juan de Fuca, a deep channel (140 fathoms) approximately 28 km wide, separates the Olympic Peninsula from Vancouver Island.

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Although broad expanses of deep water may be impediments to otter movements (Packard 1982), they are not absolute barriers, as has been demonstrated by otters recolonizing certain Aleutian Islands in Alaska (Lensink 1962; Kenyon 1969).

In Washington, spring appears to be the peak pupping season and fall the breeding season, following similar patterns of otters in Alaska (Garshelis et al. 1984) and California (Estes and Jameson 1983). Pupping rates also appear to be similar. Our record of 16 pups born in 1986 out of a population of 51 independent otters and 20 pups in 1987 from 87 independents falls close to annual parturition rates of 20 - 30 pups/ 100 independents reported for California and Alaska otters (Estes 1981; Riedman 1987). However, the lack of individually identifiable females, either tagged or naturally recognizeable, prevented us from determining if individual adult females undergo annual pupping as documented by Loughlin et al. (1981), Garshelis et al. (1984), and Wendell et al. (1984) or have biennial parturition as suggested by Kenyon (1969) and Schneider (1972). Together with the unknown mortality rates and age/ sex ratios, annual net productivity of Washington sea otters remains in question.

Although historic population levels of sea otters in Washington are not known, James Dobbins Associates, Inc. (1984) calculated a carrying capacity between 1280 to 2560 animals. This estimate was based on otters reoccupying areas (within the 20 fathom isobath) between Destruction Island and Observatory Point (west of Port Angeles in the Strait of Juan de Fuca) at a density level of 8 otters/mi^2 (3 otters/km^2). The density level was derived by applying average California sea otter densities along both rock and sand habitats to Washington. It is unknown, however, whether subtidal habitats off Washington could support the same density. With the current Washington density estimated between 0.6 - 0.8 otters/ km^2 (within the 10 fathom isobath) and a range from Destruction Island to Point of the Arches, a continued population increase and/or range expansion might be expected. However several limiting factors, such as habitat quality and mortality factors, could curtail this growth.

Quality of sea otter habitat in Washington was assessed by two methods: (1) evaluation of otter activity-time budgets and food habits, and (2) benthic surveys. Activity-time budgets, specifically frequency of feeding, have been used to interpret food availability and habitat quality on the premise that feeding rates reflect prey resource levels (Eberhardt 1977; Estes et al. 1982). The low frequency of diurnal feeding in Washington otters (9.5-11.2%) follows patterns in other areas where otters spend 15-20% of their daylight hours foraging and are not considered resource

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limited (Estes et al. 1982; Estes et al. 1986). Conversly,
otters at Amchitka Island, Alaska, believed to have been at
carrying capacity for a number of years, have to spend 50-55%
of their daylight time feeding in a resource limited habitat
(Estes et al. 1982).

There are several inherent biases, however, in interpreting
habitat quality solely on results of diurnal activity
budgets. Firstly some degree of nocturnal foraging is
probably occurring. Previous radiotelemetry studies have
shown that otters appear to forage in 2.5 - 3 hour bouts
dispersed over a 24 hour period (Loughlin 1977; Ribic 1982;
Garshelis 1983). And if a disproportionate number of otters
forage primarily at night, daytime observations would reveal
low feeding rates for the population and prey resource
levels would be overestimated (Garshelis et al. 1986).
Instrumenting Washington otters with telemetry units would
resolve this question of nocturnal feeding frequency in
relation to interpretation of resource levels (Garshelis
and Siniff 1983; Garshelis et al. 1986).

Secondly some unknown proportion of feeding otters may be
overlooked during scans when they are below the surface or
beyond visual viewing range, thereby underestimating foraging
activity. Although other studies report that this bias can
be curtailed or eliminated by scanning slow enough to view
all areas for the duration of an average 1 minute dive
(Estes et al. 1982), the greater viewing distances of our
monitoring areas precluded this technique. Therefore our
feeding rates may be conservative due to the possibility of
some missed behaviors. We believe, however, that this bias
would not substantially alter the results of our otter
activity budgets. Telemetry studies could address this
question as well.

B) Food Habits and Foraging Behavior

Previous food habit studies have shown that sea otters prey
primarily on macroinvertebrates. Although our sample sizes
were too small to reliably rank food items in the dietary
importance of Washington sea otters, they did show that
Washington otters preyed exclusively on molluscs, crabs, and
echinoderms. This pattern is similar to that recorded for
most otters in California and Alaska (Wild and Ames 1974;
Estes et al. 1981; Ostfeld 1982; Garshelis 1983; Estes et
al. 1986).

Washington otters were never observed feeding on fish and it
is unlikely that such identifiable prey would have been
overlooked in this study. In stark contrast are food habits
of otters at Amchitka Island where fish have become
substantial components of their diet. As previously

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mentioned, Amchitkan otters are at equilibrium density and their foraging pressure has reduced the availability of macroinvertebrates, presumably resulting in the shift to fish as a major dietary component (Estes and Palmisano 1974; Estes et al. 1982). The absence of fish-eating in Washington otters may therefore be an indication that invertebrate prey are still a sufficient food resource and that the population may still be below carrying capacity.

Sea otters were previously thought to be generalized predators, preying opportunistically on the most readily available resource (Vandevere 1969). However, recent evidence from tagged otters reveals that some individuals are specialist, favoring particular species despite availability of other abundant resources (Lyons and Estes 1987). This phenomena would be masked during food habit studies at the population level. Our own study, albeit limited, revealed that individual otters preyed primarily on only one or two species during each foraging bout (Table 13). Additional studies focusing on individual foraging patterns could further address the question of prey selection and the degree of individual specialization. This would be crucial in ranking prey importance at the population level.

Success rates of foraging dives are also a useful measure of sea otter habitat quality. Washington otters were highly successful foragers, recovering prey items on 88.5-89.4% of their feeding dives. This success rate compares favorably with other otter areas considered to be below carrying capacity. In California, for instance, sea otter foraging success ranged between 70-73% (Loughlin 1977; Estes et al. 1981) and otters in Prince William Sound, Alaska, showed success rates between 80-96% (Garshelis 1983).

Although otter habitat may not be resource limited as yet, evidence from benthic surveys suggests that sea otters in Washington have substantiallly reduced available prey biomass within their current range. Subtidal communities sampled within the primary otter range (Fig. 1 in Appendix 3) showed a habitat with prey biomass ranging from 31 - 98 g/m^2 and with infrequent medium to large ($\geq$ 5 cm) prey items (Table 2 in Appendix 3). Approximately twice the biomass was available in the secondary otter range (128 - 191 g/m^2). Areas just north of the current otter range revealed the greatest prey resources (318 - 776 g/m^2), approximately ten times the magnitude of the biomass within the primary range. The north area also showed an increased frequency of medium to large prey, particularly sea urchins, a major prey target of otters.

Sea otters can substantially alter benthic community structures by their voracious foraging activities on

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macroinvertebrates, leading them to be portrayed as "keystone predators" (Estes and Palmisano 1974) after Paine's (1969) original concept. This classic example of ecological interrelationships between sea otters, urchins, and kelp along rock-bottom communities has been well documented in California and Alaska (Dayton 1975; Simenstad et al. 1978; Duggins 1980). Simply stated, otter predation on herbivorous urchins reduces the grazing pressure on macroalgae, leading to dramatic increases in kelp productivity and canopy cover. Some evidence suggesting this successional pattern in Washington is revealed by photographs of Cape Alava kelp beds before and after otters arrived. *Macrocystis* kelp showed significant increase in percent cover between 1959 (pre-otter) and 1986 (Table 5 of Appendix 3). This generalization is not universal, however, as Foster and Schiel (1988) have shown other structuring factors playing important roles in the formation of kelp communities in some otter-free areas in California. Further investigations of this otter\kelp interrelationship should be conducted in Washington to determine if otters are indeed enhancing local kelp beds.

Where otter foraging has caused increased kelp canopies, a corrolary has been increased fish densities within the kelp community (Estes et al. 1978; Duggins 1980). This adds to the overall productivity of kelp bed communities and availability to related fisheries. Dive surveys around the Cape Alava kelp beds have revealed abundant midwater and benthic fish numbers, suggesting such a relationship (Table 3 in Appendix 3).

C) Sea Otter-Fishery Interactions

The carrying capacity of sea otter habitat can also be affected by resource competition between otters and shellfisheries. In California and Alaska, otters are serious competitors for shellfish stocks that are also harvested by sport and commercial fisheries (see Estes and VanBlaricom 1985 for an excellent review). At present there are no recorded otter-fishery interactions in Washington, but if and when otters expand their range north or south, they will encounter several sport and commercial shellfisheries (urchins, razor clams, Dungeness crabs) along the coast. The degree of the competition in Washington will depend on the number of animals involved, their duration of stay in the affected area, and the size of the fishery. Several potential sea otter-fishery interactions for shellfish resources in Washington are outlined below.

Sea urchins are a preferred item in otter diets, being one of the first prey species in a benthic community to undergo a reduction in abundance due to foraging otters (Lowry and Pearse 1973; Estes and Palmisano 1974). With a gradient of

increasing abundance of red sea urchins (*Strongylocentrotus franciscanus*) from Cape Alava to Neah Bay (Table 1 in Appendix 3), otters could be expected to eventually move northwards, thereby impacting the small but growing commercial fishery for red sea urchins located around Cape Flattery and Neah Bay (Mills and Solomon 1984; Alex Bradbury, Washington Department of Fisheries, pers. comm.).

Commercial and sport fisheries for Dungeness and rock crabs (*Cancer magister* and *C. productus* respectively) exists both north and south of the present otter range (Mills and Solomon 1984). If otters move into these areas and follow the foraging pattern they showed in Prince William Sound, Alaska (Garshelis and Garshelis 1984), an intense fishery competition will ensue.

To the south of the otter range, from Kalaloch (just south of Destruction Island in Figure 1) to the Columbia River, lie beds of razor clams (*Siliqua patula*), the most important shellfish species recreationally harvested on the coast (Mills and Solomon 1984). Otters are excellent underwater diggers and have foraged on razor clams in Alaska (Johnson 1982) and California (Kvitek and Oliver 1988). Presumably prey species of these soft-bottom communities, such as clams and crabs, were the resources that allowed historic population levels to thrive from Point Grenville to the mouth of the Columbia River (Fig. 1). This stretch of southern Washington coastline is dominated by long stretches of sandy beaches and is in stark contrast to the rocky coastline and rock bottom communities of the otter's present range to the north.

These potential otter-fishery competitions should be assessed by continued monitoring of otter distribution, abundance, and food habits. Any new fishery developing within the otter range should also be evaluated for potential impacts.

D) Mortality Factors

Sea otter mortality has been reported to fall into four basic categories:
>   1) environmental - winter storms, starvation;
>   2) predation - sharks, killer whales, bald eagles;
>   3) disease - enteritis and pneumonia;
>   4) human caused - net entaglement, shooting.

We do not yet know to what extent, or in what combination, the above factors are affecting Washington's sea otter population.

Winter storm mortality has been documented from otters in Alaska (Kenyon 1969) and California (Morejohn et al. 1975; Ames et al. 1983). During winter otters are stressed by colder environmental temperatures, frequent rough seas and, in the case of the Washington population with a much smaller winter range where food may be limited, competition for food resources. Prolonged severe storms would be especially threatening, forcing otters to seek refuge in protected areas and restricting their ability to disperse and forage at other feeding sites. Aleutian frontal systems bombard the Washington coast during winter with gale force winds occurring on the average of 3-5 days per month with 6 m. seas occurring 4% of the time (Oceanographic Institute of Washington 1977). Because of their high metabolic rate, otters must consume up to 30% of their body weight per day. Starved otters may lose as much as 10% of their weight per day (Kenyon 1969), with a weight loss of more than 23 - 24% over several days being lethal (Miller 1974). Previous winter storm mortality has likely gone undetected along the rugged and remote northern Washington coast since it receives relatively few visitors during that time.

Recorded predators of sea otters include sharks, killer whales, and bald eagles. Sharks have been shown to be significant predators on sea otters in California with white sharks (*Carcharadon carcharias*) being the most frequently implicated species. Ames and Morejohn (1980) speculated that from 9 - 15% of the 657 dead sea otters reported in California between 1968 and 1979 were killed by white sharks. Although the extent to which white sharks occur in Washington waters is unknown, there is at least one incident in which white shark tooth fragments were recovered from the carcass of a sea otter found on the central Washington coast (Keyes 1975). The possibility that white sharks may at least seasonally occur in nearshore areas off the northern Washington coast is also suggested by our May 1986 discovery of two dead harbor seals (one a neonate) with shark bites. Bite diameters as large as 25 - 26 cm across were observed on both animals and the presence of hemorrhage around the wounds indicated that the bites were probably the cause of death. Based on a description of the bite characteristics it was felt the shark involved was most likely a white (Jim Harvey, pers. comm.) although no tooth fragments were found.

Killer whales (*Orcinus orca*), are known to feed on other marine mammals, particularly pinnipeds, have frequently been suggested as predators on sea otters. However only one recorded instance of such predation exists (Nikolaev 1965) while most observers have reported interactions without predation (Kenyon 1969; Beckel 1980). Given that orcas have only been observed as uncommon transients through the nearshore waters of Washington's northern coast (Speich et al. 1985; this study) it is most unlikely that they pose any

significant threat to Washington's otters. Orcas were observed in our study area only twice in the course of this study and only once were they observed near sea otters. On that occasion a group of 3 orcas (1 large bull and 2 subadults) passed within 100 - 120 m. of a raft of seven otters (including mother/pup pairs) in the Cape Alava area. The rafted otters appeared to be sound asleep and totally unaware of the presence of the orcas.

Bald eagles (*Haliaeetus leucocephalus*) have been observed to prey on live sea otter pups at Amchitka Island, Alaska, although in insignificant amounts (R.D. Jones in Kenyon 1969; Sherrod et al. 1975). Given the large number of bald eagles (both nesting adults and immature birds) occurring in our study area, there is the possibility that some pup predation may occur. We never observed such predation and if it occurs at all in Washington, we feel it is probably insignificant.

The extent of pathological diseases in Washington sea otters is currently unknown. Enteritis and pneumonia have been directly related to a small proportion of mortalities in California and Alaska (Kenyon 1969; Morejohn et al. 1975; Ames et al. 1983).

Human-caused mortality, particularly as a result of fisheries interactions, is an area of concern. Fishery conflicts have occurred in California and Alaska (Wild and Ames 1974; Johnson 1982). Otters are particularly susceptible to entanglement in gillnets and this has caused significant otter mortality in California's coastal set-net fishery (Wendell et al. 1985). Commercial fishing activity within the present range of Washington's sea otters is currently low. However there is a Makah tribal gillnet fishery for salmon using marine set-nets from Cape Flattery to Point of the Arches (Dave Sones, Makah Tribal Council, Neah Bay, pers. comm.), that borders the current northern range of otters. If otters do expand their northern range and/or if the fishery moves south, the probability of fisheries-related mortality will increase. Given the small size of our current otter population, such mortality could be highly significant. In California the leveling off and decline of the otter population from 1976 to 1985 from a previously growing population was attributed to mortality from nearshore net fisheries (Riedman 1987).

E) Oil Risks to Sea Otters

The proposed leasing of tracts off the Washington coast for oil and gas exploration and development (Minerals Management Service 1987) raises serious concerns over the risks such activities could have on Washington's sea otter population. Although normal activities associated with such undertakings

would likely have little or no impact on sea otters (unless such activities were to take place in nearshore waters within the otter's range), oil spills from drilling platforms or associated sources (eg. tankers or pipelines) could result in very serious impacts on the otter population.

Sea otters lack an insulative blubber layer, as found in pinnipeds and cetaceans, and rely solely on their fur and the air entrapped therein to protect themselves from heat loss in the water. The insulative properties are lost with contact with oil, causing otters to be the most sensitive marine mammal species to direct oil contamination (Geraci and St Aubin 1980; Hansen 1985). Laboratory experiments have shown that the resting metabolic rate of sea otters increased up to 40% above normal when the animals were lightly coated with crude oil over approximately 25% of their bodies (Costa and Kooyman 1979). The elevated metabolic requirements caused by increased thermal conductance of oiled fur result in thermal stress and can lead to hypothermia and death (Siniff et al. 1982).

Results of experiments where otters have been treated with small amounts of oil and then released back into the wild while monitored by radiotelemetry have been somewhat ambiguous, perhaps because of the small sample sizes involved. Costa and Kooyman (1979) observed that otters which had been lightly oiled with 10 to 30 ml ($\bar{x}$ = 20.5 ml) of crude oil showed no significiant difference in activity levels compared to control animals and the authors hypothesized that otters may be capable of thermoregulatory compensation when only lightly oiled. In a similar experiment Siniff et al. (1982) found that otters treated with 25 ml of oil prior to release showed elevated activity levels with intense grooming (rather than feeding) accounting for the increase. It should be noted that in both experiments the release of the oiled otters occurred in mid-summer when environmental conditions (air and sea temperature, etc.) were optimal, and otters were released into areas where food was abundant. The authors of both studies emphasize that even light oiling of otters would be of much greater impact in situations where the otters were already subjected to other thermal stress such as low environmental temperatures. Similarly, any factors affecting the otters' ability to meet the greater energy demands of thermal stress due to oiling would be expected to have detrimental effects. Such factors include competition for limited food resources, loss of feeding time due to increased grooming activity or exposure to storms when rough seas reduce foraging ability of the otters while increasing their energy demands. The significance of reduced food intake is indicated by the fact that even unstressed adult otters must consume food equal to 23 to 29% of their body

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weight per day (Kenyon 1969) and that starved otters lose
10% of their body weight per day (Miller 1974).

At this time it is not known to what extent free-ranging
otters may be able to detect and avoid oil slicks. Captive
otters, however, do not avoid oil slicks (Williams 1978;
Siniff et al. 1982). Free-ranging otters are more at risk
of coming into contact with oil than are most other marine
mammal species since they spend most of their time on the
surface of the water, whether resting, grooming, feeding or
swimming. Much of this time is spent in protected areas of
low wave energy (such as the lee of islands or rocks or in
kelp beds) where oil, once present, would be most likely to
persist. The attraction of otters to kelp beds could
present special problems in that the heavier components of
oil tend to cling to kelp, thus presenting another avenue by
which otters could become contaminated by oil. Even
temporary loss of a critical habitat area (eg. an area
affording protection from winter storms) could potentially be
devastating to a localized population like that off the
Washington coast.

Another serious question regarding the potential impacts of
oil spills on sea otters regards the effects of oil on prey
species utilized by otters. Hansen (1985) suggests that
otters may be especially sensitive to reduction in prey
caused by oil spills because of their tendency to rely on
relativeley local food sources within limited home ranges,
and because they feed largely on sedantary or slow moving
benthic organisms which could be relatively sensitive to oil
spills. Given the high metabolic demands of sea otters, any
reduction in food supply (whether a result of prey
mortality, unpalatability of oil contaminated prey, or otter
avoidance of a feeding area due to the presence of oil) could
have serious repercussions. To animals suffering the
additional thermal stress of oiling, such a reduction in food
supply would likely prove fatal.

Additional concerns pertaining to sea otters are the lack of
knowledge regarding physical persistence of hydrocarbons in
sediments and the possibility of bioaccumulation of these
compounds in benthic organisms which are a major part of the
sea otter's diet (Hansen 1985). It is not currently known
to what extent such bioaccumulation could impact sea otter
prey species or if ingestion of contaminated prey could lead
to physiological changes within the sea otters themselves.

The prior discussion has been on the possible impacts of oil
spills on sea otters. It should be also noted that much
effort has been put into developing methods to contain
and/or disperse oil spills to prevent them from reaching or
severely impacating fragile nearshore environments (U.S.
Fish & Wildlife Service 1987; Minerals Management Service

1987). Containment efforts have proven useful in many
circumstances. The effectiveness of such methods, however,
is extremely dependent on two factors: the speed with which
containment devices can be deployed and the environmental
conditions at the site of the oil spill. Speed of deployment
would of course depend on the number and location of sites
at which the necessary equipment could be stockpiled and
from which response personnel could be dispatched. Coastal
areas remote from the necessary port facilities would
require a longer time to reach, thus reducing the time
available to respond to the spill before it spreads beyond
containment bounds.

The ability to effectively use physical containment and
cleanup equipment, assuming it can be deployed in time,
depends greatly on sea conditions at the spill site.
Because available containment methods become ineffectual when
combined swell and wave height exceeds several feet
(Minerals Management Service 1987), it is generally accepted
that physical containment is not likely to be a viable option
for many open coastal settings (like Washington's Olympic
Peninsula) under the normally prevailing sea state
conditions.

Another tool for ameliorating the impacts of oil spills is
the use of dispersants, which are detergent-based chemicals
used to break down heavy concentrations of oil. While the
use of such chemicals may be appropriate in some settings,
there is increasing concern over their use in nearshore
environments. Of major concern are the potential effects of
solvent-emulsifiers on marine mammals and seabirds, and on
the aquatic and benthic organisms of nearshore and
intertidal ecosystems. It is possible that in some cases
exposure to these chemicals may be more harmful to wildlife
than exposure to the oil itself (Geraci and St Aubin 1980).
In laboratory experiments where oiled sea otters were
cleaned with detergents, metabolic rates of the animals
(immersed in 15°c water) increased up to 110% above normal
due to the detergent reducing the insulatiave properties of
the fur. Two of the three animals thus treated developed
pneumonia as a result of the severe thermal stress.

In the event of an oil spill which could not be contained or
safely dispersed, the last available option would be to
attempt capture of sea otters threatened by imminent oiling
or the capture and rehabilitatin of oiled otters. Such
attempts would require considerable expense and effort with
minimal chance of success. Capture methods (both passive
and active) currently available for sea otters would not be
adquate in cases where large numbers of otters needed to be
rescued in a relatively short period of time (Williams 1978;
Packard 1982). Also, because of the logistical complexity
of staging a capture operation (needs for vessels,

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specialized equipment, trained personnel, etc.) capture of
animals to prevent oil contamination would require more lead
time than would likely be available in the event of an oil
spill. Any decision to attempt capture operations would of
course be dependent on suitable environmental conditions at
the proposed capture site.

Once a decision has been made to capture otters for
preventitive or treatment purposes, appropriate means of
dealing with any rescued otters must be enacted. For unoiled
otters this would entail either transplanting the otters to
another site not threatened with exposure to oil or
maintaining the otters in holdling facilities until such
time as they could be safely returned to the wild. Oiled
otters would need extensive treatment and rehabilitation
under veterinary care. Costa and Kooyman (1979), following
extensive experiments dealing with the treatment of oil-
fouled otters, state that "Rehabilitation of oil-fouled sea
otters would be very costly requiring holding facilities to
keep the animals for at least two weeks. Even if adequate
facilities were available, the success rate of rehabilitating
oil-fouled sea otters is likely to be rather low."

The preceding discussion has dealt with the general effects
of oil spills on sea otters. Specific concerns related to
the potential effects of an oil spill on Washington's sea
otter population are as follows:

> 1) Washington's small population (107 to 136 animals)
> inhabits a limited range with the entire population
> currently found along just 70 km of coastline. Criti-
> cal habitats such as feeding and sheltering areas
> within the current range are limited in number and
> patchily distributed. Because of this, large segments
> of the population are seasonally concentrated in very
> limited areas. In September of 1987, for example, a
> total of 84 otters were found to be congregated in the
> Cape Alava and Duk Point areas (about 9 km of
> coastline). Our best evidence to date suggests that
> this local concentration is present from approximately
> September to April. Other seasonal concentrations are
> found in the vicinity of Sand Point in early and late
> summer, and at Cape Johnson during mid-summer.
>
> Costa and Kooyman (1979) in evaluating the effects of
> oiling on sea otters concluded that "A large scale oil
> spill within an area populated by sea otters could
> result in oil fouling of most of the sea otter
> population and would most likely result in death for
> those animals oiled." The combined factors of small
> population size and seasonal concentration of large
> segments of the population make the Washington popu-
> lation exceptionally vulnerable to impacts from oil.

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Even a relatively small spill could potentially decimate the population. Perhaps the worst case scenario would involve a winter spill of crude oil reaching the Cape Alava area. Not only is most of the population concentrated in that area during the winter months, but also this is the time of the year when otters are most likely to be under the additional physiological stresses brought about by cold temperatures, winter storms and competition for limited food resources. Prevailing winter weather and sea conditions would likely make any attempt at either oil spill containment or otter rescue impractical. In addition, any oil which reached the nearshore area would persist longest in those low wave-energy areas where otters congregate to seek shelter from rough seas. Even if otters were able to escape oiling they would quite possibly be excluded from oil-fouled feeding areas and thus be susceptiable to starvation.

2) The geography and environment of the northern Washington coastal areas in which the sea otter population is located present some special probems relative to oil spill containment and cleanup operations.

Most of this area lies within Olympic National Park and is inaccessible by road. The nearest harbors from which cleanup vessels and equipment could be deployed are Neah Bay to the north and La Push to the south, with the latter being restricted to use by fairly small vessels. It is questionable as to whether either of these locations would be satisfactory for stockpiling of emergency oil control equipment and vessels. More likely sites would be Port Angeles (in the Strait of Juan de Fuca) or Westport (in Grays Harbor). Both are larger ports in areas of heavy shipping traffic where more frequent small oil spills would be expected and proximity of oil control equipment would be highly desireable. The remoteness of the northern coast from those areas where oil containment equipment and personnel are likely to be located make response time an especially critical factor, particularly if the origin of the spill is close to shore.

Apart from the remoteness of the northern outer coast, the nature of the environmental conditions prevailing in that area for much of the year are likely to be a major factor determining the feasibility and effectiveness of oil containment

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operations. Sea states typically exceed those
considered practical for containment operations or
the use of dispersants, and storms and coastal fog
are common occurrences during many months. Because
of the rugged nature of the northern coast with its
many reefs, rocks, islands, headlands and kelp beds
it would be necessary to contain any spills well
offshore to protect the complex and fragile
nearshore ecosystem. Any oil slick reaching these
areas would be impossible to remove by physical
means and use of dispersants in these areas would be
equally undesirable given their possible effects on
marine mammals, seabirds, nektonic, and benthic
organisms.

3) The practicality of attempts to capture otters
either to prevent their exposure to an oil slick or
to treat otters already oiled is highly questionable
as mentioned previously. Currently used capture
methods may not be discriminating enough to
selectively take individual otters (the use of the
diver-held basket trap being precluded by poor
underwater visibility (Wild and Ames 1974), commonly
found along our coast) nor effective enough to
capture large numbers of otters during a short time
(Packard 1982; Hofman 1985). An additional problem
is that at the present time neither the necessary
capture equipment nor personnel trained in its use
are available within the state of Washington. Until
such time as local personnel and equipment are
available, any capture attempts would have to be
mounted by personnel from out of state, thus bringing
into question the availability of such resources on
an emergency basis.

A related problem is the current lack of sufficient
holding and/or rehabilitation facilities locally
to deal with the potentially large number of
oil-fouled otters which could result from an oil
spill.

In reviewing the current state of knowledge of the impacts
of oil spills on sea otters and the current state of
preparedness of Washington state to deal with an oil spill
on the outer coast, we feel that serious attention needs to
be focused on the following research needs and oil-spill
response resources.

1) Gathering detailed information on nearshore
surface circulation patterns in order to have some
predictability as to the trajectory of oil spills.

2) Determining the effects of oil on nearshore nektonic and benthic organisms. Areas of concern include toxicity, sublethal effects impacting productivity or growth, and the potential for bioaccumulation of harmful hydrocarbons.

3) Investigation of the effects of solvent-emulsifiers (dispersants) on free-swimming otters and on nearshore aquatic and benthic organisms.

4) Studying the possible toxic effects of oil on sea otters, whether by direct ingestion or via bioaccumulation in the food chain. Research should include the possibility of sublethal physiological effects.

5) Establishing a local response team capability for emergency sea otter capture operations as well as the holding/rehabilitation facilities necessary to handle oiled otters.

6) Conducting the necessary research to evaluate otter survival and recruitment rates in order to better assess the potential impact of oil spills on the population and predict the recovery potential following loss of a portion of the population.

F) Protective Status

Because Washington sea otters are still in a precarious status due to their small population size and restricted range, the State of Washington classifies them as an "endangered species" (WAC 232-12-014 in Washington Dept. Wildl. 1988). They are also afforded federal protection by the Marine Mammal Protection Act but are not listed as "endangered" or "threatened" under the Federal Endangered Species Act. The latter is an legal artifact due to the original transplants coming from Alaskan stock (not listed) rather than from the "threatened" California stock (Greenwalt 1977).

Sea otter habitat is also afforded some protection in Washington. Land areas within the present otter range fall under jurisdictions of the U.S. Department of Interior (Olympic National Park and Flattery Rocks and Quillayute Needles National Wildlife Refuges) and tribal governments (Makah, Quileute, and Hoh). Marine waters out to three miles are considered Washington State territorial seas. The coastal waters, from Cape Flattery to Point Grenville, including all areas surrounding the offshore islands of the wildlife refuge system, have been listed as a potential site for a national marine sanctuary under the sanctions of the

Marine Protection, Research, and Sanctuaries Act (U.S. Dept. Commerce 1983). However the aforementioned proposed oil and gas lease activities could still jeopardize the majority if not the entire coastal habitat and the Washington sea otter population.

CONCLUSIONS

This 1986 and 1987 study of Washington sea otters revealed
the following:

1. Highest population count was 107 (including all
   age classes) and the total population was esti-
   mated to be 136 individuals.

2. Pup production, spring through summer, ranged
   from 16 in 1986 to 20 in 1987.

3. Otters ranged from Destruction Island to Point of
   the Arches, some 70 km of coastline; seasonal
   population shifts occurred.

4. Interpretation of diurnal activity-time budgets
   suggested that Washington sea otters are not cur-
   rently resource limited, although benthic surveys
   revealed they had substantially reduced the
   biomass and abundance of major prey species within
   their current range.

5. Food habit studies revealed that Washington otters
   foraged exclusively on macroinvertebrates: clams,
   chitons, sea cucumbers, octopus, crabs, and urchins.

Although Washington sea otters would be expected to show a
continued growth rate and an eventual range expansion,
several potential threats to this recovering population loom
in the future. If and when range expansion occurs, otters
will increasingly encounter various commercial, sport and
tribal fisheries. Predicted impacts will range from inciden-
tal drownings in net fisheries to resource competition with
man for the same shellfish resources.

The entire population may be at even greater risk from the
proposed leasing of offshore waters for oil and gas
development. Sea otters are known to be the most susceptible
marine mammal to oil contamination, which can lead to hypo-
thermia and death. Any spill or discharge affecting the
limited range of the Washington otter could therefore jeopar-
dize a major portion if not the entire population.

RECOMMENDATIONS

While this research addressed several important aspects of population demographics and behavioral ecology of Washington sea otters, additional studies are required to continue monitoring the health of the small population and to fill in several important data gaps. This is especially critical in light of several potential threats that could befall the recovering population: 1) proposed oil and gas development off the coast; 2) incidental drowning in nearby netfisheries; and 3) potential resource competition with neighboring commercial and sport shellfisheries.

The minimum data requirements should include additional surveys, using combinations of air and ground teams, to detect interannual changes in population numbers and distribution. Early spring or fall surveys are recommended since most of the Washington sea otter population are aggregated around the Cape Alava region, thereby fascilitating counts. Spring surveys, in addition, would provide indexes of pupping levels. Surveys should be scheduled to avoid minus tides since many otters haul-out on rocks at this time and are easily overlooked, especially by aerial observers.

Offshore distribution of sea otters should be examined in more detail. We surveyed all known otter areas within the 10 fathom isobath but did not attempt to identify offshore ranging. Radiotelemetry and offshore flight transects could evaluate offshore use patterns by Washington otters.

Although the Washington otter population was surveyed from spring through fall, no winter monitoring was conducted. This is a critical season since otters are apparently aggregated along a small portion of the coast and are more susceptible to environmental stress or man-made catastrophes. More detailed information is needed on distribution, habitat use patterns, and mortality factors during this season.

Recruitment rate is a critical data gap that needs to be evaluated. In addition to determining seasonal pupping levels, the question of whether Washington otters undergo annual or biennial parturition needs to be examined and pup survivorship determined. Tagging and radiotelemetry studies would address these issues.

Mortality rates and causes are still unknown for the general population and need to be evaluated in order to assess annual net productivity. Tagging studies and beach salvage efforts are recommended.

In addition to population demographics, continued assessment studies of habitat quality and resource availability should be conducted. Sea otter food habits should be monitored for all seasons to more reliably rank prey importance. Feeding behavior of identifiable individuals and different age/sex classes should be emphasized using tagging and/or telemetry techniques. Nocturnal activity patterns could also be investigated by radiotelemetry with the results correlated with diurnal activity budgets as an additional assessment of habitat quality and resource availability.

Research sampling stations to characterize subtidal communities, both within and outside of the current sea otter range, should be expanded and monitored frequently enough to detect seasonal or interannual changes in community structure. This could be a predictive tool to forecast otter range expansion.

Coastal mapping of kelp beds and species composition should be initiated immediately in order to inventory preferred otter habitat. This would also establish baseline data to examine the interrelationship of sea otter foraging effects on kelp community structure.

Sea otter/fishery interactions should be documented and monitored as they occur. Of particular concern should be nearby netfisheries that could result in entanglements/drownings. Resource competition with neighboring sport and commercial shell-fisheries should be evaluated if the otters move into areas of conflict.

Developments of oil and gas leasing efforts should be followed closely. If leasing occurrs, stringent management plans need to be developed to mitigate potential impacts on the small, range-limited sea otter population in Washington.

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Appendix 1.

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6. May 1975. J. Smith, WDW[b], personal communication. Two
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20. July 24-27, 1985. Jameson et al. 1986 (excluding
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    (sea otters seen near Tatoosh Island).
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    (6 sightings of a single individual in Neah Bay).
23. June 28, 1978. B. Pittman, WDW Nongame data file.
24. May 4, 1980. WDW ground count.
25. Summer, 1977. J. Smith, WDW Nongame data file (1 dead
    pup at Sand Point).
26. July 20, 1984. S. Jeffries, WDW aerial survey log.
27. June 5, 1985. C. Bowlby, WDW field log.
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32. August 6, 1977. S. Jeffries, WDW aerial survey log.
33. August 12, 1978. S. Jeffries, WDW aerial survey log.
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35. May 28, 1985. S. Jeffries, WDW aerial survey log.

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        [b] Washington Department of Wildlife
        [c] University of Washington.

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Appendix 2

Sightability codes used during scan surveys.

Excellent -   Water surface calm. No glare problem.
               Excellent lighting conditions. Able to see
               all otters on the surface.

Good -   Water with light ripples or low swell. May
               be some harsh lighting on water but no
               significant glare problem. Lighting good
               overall. Only slight probability of
               missing an otter on the surface.

Fair -   Water surface conditions (chop/swell) and/or
               glare creating significant visibility
               problems within the scan area. Light
               levels may be too low to permit
               good definition of objects on water
               surface. Moderate probability of missing
               an otter on the surface.

Poor -   Water surface conditions and/or glare
               conditions creating serious visibility
               problem within the scan area. High
               probability of missing an otter on the
               surface.

Final Report

CHANGES IN ROCKY SUBTIDAL COMMUNITIES WITHIN A GRADIENT OF SEA OTTER PREDATION ALONG THE OLYMPIC PENINSULA COAST, WASHINGTON STATE

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Abstract

Distribution and abundances of benthic species were sampled within and outside of known sea otter feeding areas along the outer coast of the Olympic Peninsula during the summer and fall of 1987. This survey had four main objectives. 1) To install permanent monitoring stations and collect baseline data on important community members. 2) To determine the distribution and abundance of sea otter prey along the coast. 3) To infer changes in benthic community structure as a result of the introduction of sea otters to Washington in 1969-70. 4) To predict future shifts in the distribution and dynamics of the present otter population based on prey abundance patterns as well as human and environmental factors.

The results of this benthic survey suggests that the introduction of sea otters has profoundly affected the distribution and abundance of their prey along the Olympic Peninsula, particularly with respect to the red sea urchin, *Strongylocentrotus franciscanus*. The lowest benthic prey biomass (98 - 31 g/m^2) was found at the sites sampled within the primary range of the sea otters (Cape Alava - Cape Johnson areas) where prey species are scarce (1.1 - 6.4 ind/m^2), and small (77 - 56% of the prey < 5 cm). At sites within the secondary sea otter range (areas where otters are only occasionally seen) prey was still scarce (< 4.5 ind/m^2), but with moderately higher prey biomass (128-191 g/m^2) and prey sizes (43-92 % of the prey ≥ 5 cm). The richest prey communities were found at the four sites to the north of the present sea otter range (Anderson Point to Neah Bay). Prey biomass (318 - 776 g/m^2) and density (4 - 22 ind/m^2) generally increase along a south-north gradient. Prey individuals were also consistently larger north of Cape Alava (66 - 89% of the prey > 5 cm). North of the otters' range, the red sea urchin accounted for most of the prey individuals and biomass. Within the range, urchins were rare, with sea cucumbers (*Cucumaria miniata*) and small gastropods making up most of the available prey items.

The distribution of red urchins appears to affect algal groups differentially. Comparing sites with and without urchins, the abundance of folios red algae was negatively related to urchin numbers whereas that of coralline crusts was positively correlated. Urchin abundance appeared to have little impact on the annual kelp species *Nereocystis.* No significant difference in the percent cover of this species was found between the site in the center of the otter range with the lowest number of sea urchins (Cape Alava, 32±0.5 % cover) and the site with the highest urchin density (Neah Bay, 34±8.8 % cover). Cover of the perennial species, *Macrocystis*, may have increased at Cape Alava since the introduction of sea otters to the outer coast. Significantly higher *Macrocystis* cover was found in aerial photographs of Cape Alava taken on June 11, 1986 (59% ± 3.2) 16 years after the introduction of otters than those taken of the same site on July 13, 1959 (32% ± 8.8) 10 years before the introduction.

If the sea otters of the Olympic Peninsula have reduced the abundance of their benthic prey base and are now faced with an impoverished resource, as a population they have four non-mutually exclusive alternatives: 1) stay where they are but at a reduced population growth rate or in reduced numbers; 2) stay

where they are and maintain the same or higher rate of increase by switching to an alternate prey resource; 3) move south into an only slightly better prey area or 4) move north into the rich and unexploited feeding grounds around Makah Bay, Cape Flattery and into the Strait of Juan de Fuca. The first option may be exercised by all or just a portion of the total population as has been documented in other areas (i.e. it may become a female area). The second option is also possible given the high numbers of fish found at Cape Alava (4.8 ± 3.2 ind/50 m transect). More fish were observed at this site than any other with the exception of Neah Bay. Moving south would provide little advantage in prey and would expose the otters to greater wave exposure (fewer off-shore island than in their present range) as well as increased human contact (Native American net fisheries and boat traffic around La Push). Finally, to move north would appear to offer the greatest rewards in terms of prey and protection from swell (once north of Portage Head and especially inside the Strait of Juan de Fuca). However, human contact may be an important deterrent; Native American fishing activity increases in this region and the Strait is also the site of an active and increasing sea urchin fishery. We conclude that scarcity of prey in the otters' present range, combined with a south to north gradient of greatly increasing prey and fishing activity sets the stage in Washington for another man/otter conflict.

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Appendix

1. Introduction

In 1969-70, 59 sea otters were translocated from Alaska to the outer coast of the Olympic Peninsula, Washington State (Jameson et al. 1982). Although, prior to our study, no quantitative benthic survey had been conducted along this coast, either to evaluate sea otter prey availability, the impact the otters have had on their communities, or for any other reason, this information is needed for several reasons. Sea otters have been generally characterized as "keystone" predators in rocky, kelp communities where their importance is disproportionately large with respect to their numbers. Although widely accepted, the paradigm of increasing kelp cover with the reduction of grazing invertebrates by sea otter predation is based on comparisons of Alaskan areas with and without sea otters (Estes and Palmisano 1974, Estes et al. 1978) or human manipulations of sea urchins in the absence of sea otters (Duggins 1980, Dayton 1975); it has never been directly tested. In addition, expanding sea otter populations have a tendency to compete with man for the same resources (see Estes and VanBlaricom 1985 for review) often resulting in heated and costly conflicts between conservationists and fisheres. Finally, California sea otters are listed as an endangered species by the US Fish and Wildlife Service, and hence the efforts at translocation to help bolster their numbers and the intense interest of environmental groups in the otters' well being.

Given the lack of critical tests, the potential for man/otter conflicts, and the demonstrated human concern for this species, there is a need for more information regarding the impact of sea otters on their prey communities and the factors contributing to the re-establishment of this species. The successful re-introduction of sea otters to the Washington coast has provided an excellent opportunity to increase our knowledge in these areas. The distribution of otters along the coast is well known (Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data), making it possible to identify and exploit a gradient of sea otter predation as a natural experiment. To this end, our project has 4 primary objectives: 1) the evaluation of prey resources within the sea otters range; 2) the comparison of prey abundance and community structure between areas of high, low and no otter densities as a correlative test of the otter/grazer/kelp paradigm; 3) the compilation of subtidal community baseline data and the establishment of permanent, long-term monitoring stations within and outside the present sea otter range. This long-term approach will provide a more direct test of the theory by allowing us to track changes in communities as the otter population continues to expand. 4) The final objective is to make predictions about the future distribution and movements of otters along the Washington coast based on factors we identify as most important in determining their present range.

2. Methods

2.1. Study Site Selection

Three broad study regions were selected with respect to the current range of the Washington State sea otter population (Figure 1). To characterize benthic communities within areas of high, low and no otter occurence, sites where selected along a gradient of otter occupancy identified by Bowlby and Troutman (Washington State Dept. of Wildlife unpublished data) (Figure 2).

Areas are designated as primary range (frequent sighting of numerous otters), secondary range (< 1 sea otter observed per survey flight), and outside the range (no otter sightings). Within the otters' primary range, sites at Cape Johnson and Cape Alava were chosen that had been identified by Bowlby and Troutman (Washington Dept. of Wildlife) as principle feeding areas (Figure 1). Specific sampling sites were then placed in the region of highest prey concentrations within each feeding area.

Olympic Peninsula Washington State

- primary sea otter ranges
- secondary sea otter ranges
- benthic survey study sites

Makah Bay
Anderson Pt.
Portage Head

Pt. of the Arches

Koitlah Pt.
outside
inside
Neah Bay

Tatoosh Isl.

Bodelteh Is.
Cape Alava
Ozette Is.

Seattle
Western Washington

Lake Ozette

Jagged Isl.

Cape Johnson

Rock 305

Teahwhit Head

LaPush
James Isl.

Middle Rk.
Destruction Isl.

Figure 2. Prey biomass was lowest at sites within the sea otters' primary range (the region in which sea otters were most frequently observed on 7 monthly survey flights between March - Oct 1987, Bowlby and Troutman Washington State Dept. of Wildlife unpublished data). Prey biomass was intermediate at sites within the secondary range (areas with < 1 sighting/flight) and was highest outside the sea otters' range. Mean otter counts (error bars = se) are for geographic areas which include the corresponding benthic study sites.
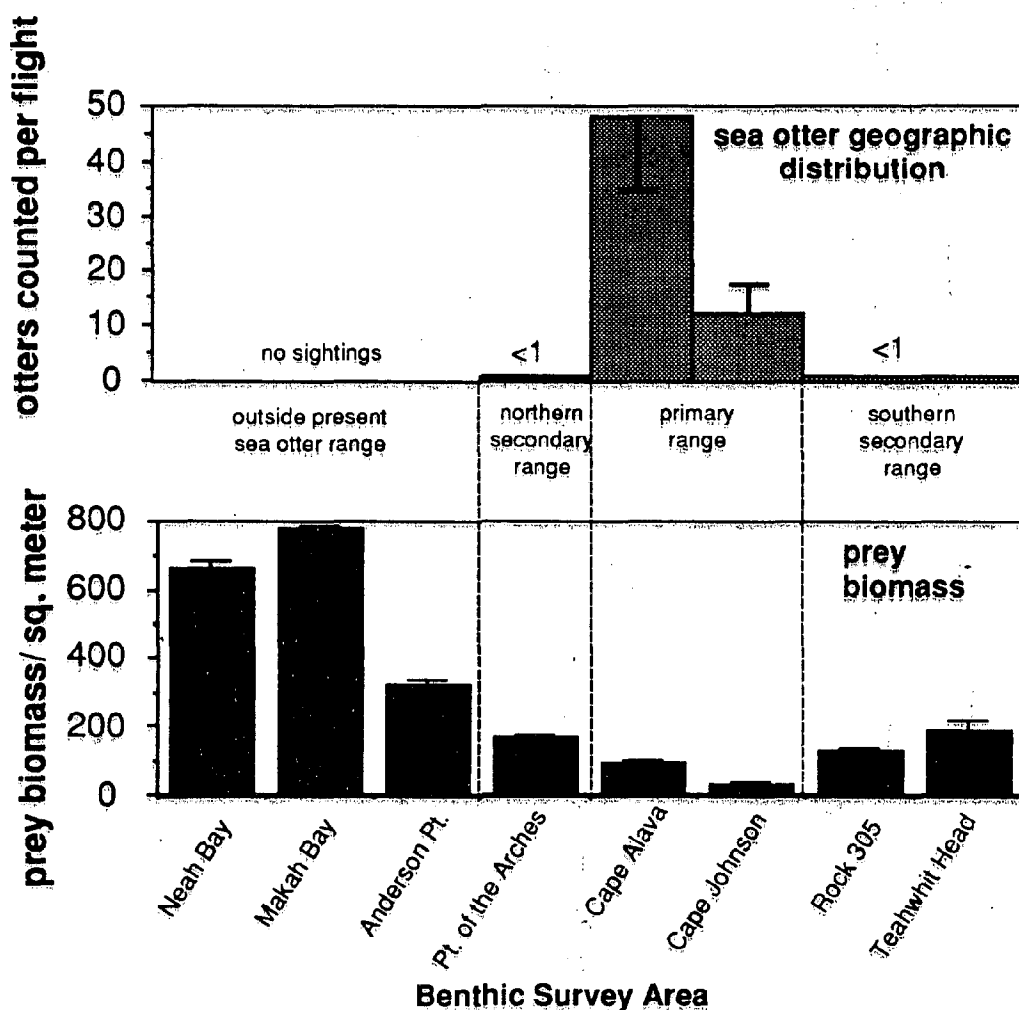
Sites outside the primary range of otters were selected based on the following criteria: protection from swell via head lands or offshore islands, water depth and substrata similar to within range sites, highest concentrations of prey locatable given the first two constraints. The southern secondary range sites (Figure 1) were placed at Teahwhit Head and rock # 305 (United States Fish and Wildlife Service coastal inventory designation). Sites to the north were placed at Point of the Arches, Anderson Point, Makah Bay and Neah Bay (Figure 1). Two sites were used at Neah Bay, one inside an area in which commercial urchin fishing is prohibited by the Makah Nation, and one outside. Urchins were actively being harvested from Neah Bay in November when our sampling was done at this site. A large area at each site was extensively surveyed qualitatively using scuba to insure the specific study location (transect site) was representative of the general area. Although a small resident otter population (~ 5) is known to occupy Destruction Island (Figure 1)(Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data), this area was not included in the quantative survey due to its periferal status and remote location.

Three sites, one in each type of study area were selected as principle study sites; Anderson Pt. outside the present otter range and to the north, and the two permanent monitoring sites Cape Alava within the primary range and Teahwhit Head in the southern secondary range. These were chosen as type communities and were more thoroughly sampled than the other sites.

2.2. Transect Layout and Installation

To promote the comparison of our results with those of researchers in other geographic areas and hence improve our ability to generalize about the impact of sea otters on their prey communities, transect layout and data collection procedures followed the protocol used by USFWS in their monitoring of sea otter habitats (USFWS 1986) whenever possible.

All field work was conducted during the last two weeks of August 1987 with the exception of Neah Bay which was sampled on November 4th. Zodiaks, a 19 ft Glasply skiff and a commercial urchin harvester were variously used as diving platforms.

Two types of transect layouts were employed, permanent and temporary. Permanent transect markers were installed at Cape Alava and Teahwhit Head. These consisted of a 50 m baseline with 5 - 14 m transect lines projecting from alternating sides every 10 m. The end of each line was marked with a stainless steel 1/4 x 4" eye-bolt and numbered stainless steel tag. The bolts were screwed into 7/16" plastic Curtis Industries wall anchors inserted into the rock. A Chicago Pneumatic air hammer, modified to operate off of a scuba tank, was used to drill the 1/2" holes required for installation. Temporary 1/4" nylon transect lines marked at 1 meter intervals could then be clipped to the eye-bolts and data collected.

At all other sites temporary transects were deployed and their positions well noted with surface line-ups such that they could be relocated within at least 10 m. These transects generally consisted of one or more series of 25 or 50 $1m^2$ quadrat counts placed end to end.

2.3. Data Collection
2.3.1. quadrat counts

At the permanent transect sites, 10 - 1m^2 quadrats were placed end to end on both sides of each transect line providing 20 quadrats per line and 100 per site. A two meter long section at each end of the 14 m transect lines was excluded to account for any disturbance that may have resulted from the bolt installation process.

Invertebrate and brown algal individuals were counted by species within each quadrat. Species deemed to be either potential otter prey, important or conspicuous community members (with the exception of clonal organisms) were sampled at most sites (see appendix tables 1,2 and 3 and for complete list of species monitored).

2.3.2. point contact

Point contact methods were used to quantify biotic cover, water depth and substratum type at the two permanent monitoring stations (Cape Alava and Teahwhit Head) and at Anderson Pt.

2.3.2.1.biotic cover

Biotic cover was determined along each transect line by noting substratum cover under each of 5 predetermined points per meter. Substratum types were classified as; folios red algae, coralline algal crust, brown algae, sessile invertebrate, or bare rock. Percent cover of each type was calculated for each of the primary study sites. Percentages were arcsine transformed and between site comparisons made via ANOVA and Fisher PLSD multiple range tests. Cover at Neah Bay was qualitatively noted.

2.3.2.2. site physical characteristics

Water depth was measured at one meter intervals along each transect line and then corrected to mean low water. Substratum type was also noted every meter and classified as either: sand, gravel, cobble (5-10 cm), small rocks (10-50 cm), large rocks (50-150 cm), boulders (> 150 cm), or bed rock. Mean percent cover of each type was then computed for each site. Substratum relief was characterized by a rugosity index. This was the ratio of the bottom contour distance between the end points of each transect line and the straight line distance (14 m) between the points. The contour distance was determined by attaching a meter tape to one end of the transect line and then following the bottom topography with the tape until reaching the other end of the transect.

2.3.3. species collections
2.3.3.1. species list

In addition to the quantitative sampling, a general list of species observed throughout the course of the study and the relative abundances of invertebrate species was also compiled (appendix tables 2 and 3).

2.3.3.2. size distributions and biomass

Size distributions of the major benthic invertebrates were compiled at each site. Individuals were either measured *in situ* or collected and measured on shore. In addition to sizes, total weights and wet meat weights were obtained for likely sea otter prey species. These measurements were then used to calculate size/weight regressions whenever possible (appendix table 6) and combined with density data to compute sea otter prey biomass concentration at each site.

2.3.4. fin fish transects

Sea otters have been shown to feed on fish in habitats where invertebrate prey is scarce (Estes et al. 1981). For this reason, fish abundance was quantified as a potential alternate prey resource at Anderson Pt., Cape Alava and Cape Johnson. Fish counts by species were made along 3 mid-water (2 x 2 x 50 m) and 3 benthic (1 x 2 x 50 m) swimming transects at each of these sites. The fish transects were run off of the ends of the quadrat transects; first the mid-water counts, then the benthic counts on the return. Fish abundance was qualitatively noted at Neah Bay and Teahwhit Head.

2.3.5. aerial kelp canopy survey

The ability of sea otters to limit the densities of macro-grazers, particularly sea urchins is well accepted, and the ability of urchins to greatly reduce kelp canopy cover is also generally acknowledged. As a test of the applicability of this paradigm to the coast of the Olympic Peninsula, contemporary and historic kelp cover comparisons were made of areas with otters vs those without or at a pre-otter time. Cover of the annual kelp species *Nereocystis luetkeana* was measured from aerial photographs taken of the transect sites at Cape Alava from 500 ft on September 17, 1987, and at Neah Bay on November 14, 1987 from a high vantage point. Percent cover was computed by projecting the photographs onto a pattern of random dots divided into quadrats and counting the proportion of dots contacting kelp plants. No winter storms had struck the coast prior to taking the photographs, and the kelp beds were fully intact. As a measure of within site variability of *Nereocystis* percent cover, annual photographs (courtesy of R.T. Paine, Zoology Dept. Univ. of Washington) taken every September from 1976-1986 of a Nereocystis patch on Tatoosh Island (Figure 1) were analyzed in the same manner.

Similarly, a July 13, 1959 aerial photograph taken at 500 ft of Ozette Island at Cape Alava by Vic Scheffer, was compared to a June 11, 1986 aerial photograph of the same area taken at the same altitude and angle (Ed Bowlby, Washington Dept. Wildlife).

3. Results

3.1. Invertebrate Prey

3.1.1. abundance

At sites north of the sea otter range, overall invertebrate prey abundances patterns were dominated by the red sea urchin, Strongylocentrotus franciscanus (Table 1). Numbers of urchins increased significantly along a south to north gradient from Cape Alava. From Cape Alava south, urchin densities were very low (0.02 - 0.22) and although more were found south of the otter range, this difference was not significant at the p = 0.05 level (Table 1). Within and south of the sea otter range, prey items were generally smaller species, with gastropods, limpets, small chitons and sea cucumbers (the only large prey) the most abundant species found (Table 1). Cape Alava had the highest overall prey concentration of the four southern sites, but gastropods accounted for ~ 75% of the prey (Table 1).

Faunal and algal species sampled but not included as prey are listed with their abundances (when available) in the appendix (tables 2-5).

Table 1. Sea otter prey abundances (means and SD) at sites within and outside of the primary sea otter range along the outer coast of Washington state. Commercial harvesting of sea urchins is not permitted inside of the Makah reserve. Alpha superscripts indicate ANOVA and Fisher PLSD multiple range test groupings at $p \leq 0.05$.

Sea Otter Invertebrate Prey Abundance (ind/m2)

Site	Strongylocentrotus franciscanus	sea cucumbers	Cryptochiton stelleri	Hinnites giganteus	gastropods	limpets	small chitons	crabs	Total Prey	N
sites north of primary sea otter range										
Neah Bay inside Maka reserve	21.1[a] (9.36)	0.24†[c] (0.59)	0.04[b] (0.20)	0[b] (0)	0.70[c] (2.17)	0.24[b] (0.59)	ns	0[b] (0)	22.4[a] (10.16)	50
Neah Bay outside Maka reserve	12.3[b] (9.66)	0.36†[c] (0.66)	0.04[b] (0.20)	0[b] (0)	0.56[c] (1.07)	0.40[b] (0.86)	ns	0[b] (0)	13.5[b] (9.91)	50
Makah Bay	6.69[c] (3.63)	0.10††[c] (0.31)	0.06[b] (0.24)	0.02[b] (0.14)	0.59[c] (1.72)	0.67[a] (1.01)	0.33[b] (0.46)	0[b] (0)	8.5[c] (4.45)	49
Anderson Pt.	3.33[d] (2.61)	0.27††[c] (0.59)	0.02[b] (0.14)	0[b] (0)	0.29[c] (0.70)	0.06[c] (0.31)	0.04[c] (0.20)	0[b] (0)	4.0[e] (2.99)	99
Pt. of Arches	4.42[d] 5.02	0††[c] (0)	0.11[b] (0.32)	0[b] (0)	ns	0[c] (0)	0[c] (0)	0[b] (0)	4.5[e] (5.07)	35
sites within primary sea otter range										
Cape Alava	0.02[e] (0.14)	0.93††[b] (1.65)	0[b] (0)	0.03[b] (0.22)	3.95[a] (4.79)	0.65[a] (1.18)	0.59[a] (0.85)	0.18[a] (0.50)	6.4[d] (5.81)	100
Cape Johnson	0.0[e] (0.0)	0.22††[c] (0.82)	0.02[b] (0.14)	0.14[a] (0.76)	0.32[c] (0.55)	0.16[b] (0.47)	0.20[b] (0.25)	0[b] (0)	1.1[f] (1.54)	50
sites south of primary sea otter range										
Rock 305	0.10[e] (0.30)	1.06††[b] (1.82)	0.1[b] (0.3)	0.1[a] (0.36)	1.18[b] (1.79)	0.96[a] (1.84)	0.30[b] (0.43)	0.02[b] (0.14)	3.8[e] (3.18)	50
Teahwhit Hd.	0.22[e] (0.61)	1.31††[a] (2.21)	0.26[a] (0.5)	0.19[a] (0.46)	2.01[b] (3.77)	0.06[c] (0.28)	0.10[b] (0.27)	0.15[a] (0.5)	4.3[e] (4.67)	100

ns not sampled   †Stichopus californicus   ††Cucumaria miniata

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3.1.2. prey biomass and size distributions

The highest concentrations of large prey items and total prey biomass were found outside the primary and especially north of the sea otter range (Table 2 and Figure 2). North of Cape Alava total prey biomass was much higher, and prey individuals > 5 cm in size represented > 80% of the prey sampled. South of Cape Johnson, biomass increased by approximately a factor of two, but prey size remained small, with half or more of the prey being < 5 cm. The smallest overall prey size was found at Cape Alava (77% of the items < 5 cm) and the lowest biomass was found at Cape Johnson.

3.2. Fin Fish

Unlike invertebrate biomass, fin fish abundance was not always reduced within the sea otter range (Table 3). Of the three sites quantitatively sampled, significantly more fish and suitable prey species were counted at Cape Alava. Only at Neah Bay were more fish observed.

3.3. Biotic Cover

Folios red algal cover was negatively correlated with the presence of sea urchins whereas coralline algal crust and bare rock cover was positively correlated with urchin abundance (Table 4). No pattern was found in the distribution of brown algal or sessile invertebrate substratum cover between sites.

3.4. Kelp Canopy Cover

Nereocystis cover at the site with the highest urchin density and no sea otters (Neah Bay) was not found to be significantly different than that found in the middle of the sea otter range (Cape Alava)(Table 5). Macrocystis cover, however, was found to be significantly less at Cape Alava ten years before the introduction of sea otters (1959) than 17 years following the introduction (Table 5).

3.5. Physical Characteristics

The three principle study sites (those sampled most intensively) were similar in water depths (4.0 - 4.8 m MLW) (Table 6) and all other study sites were within this depth range. Rugosity was somewhat higher at Cape Alava and Teahwhit Head than Anderson Pt. which had a higher percentage of small rocks and gravel (Table 6). Large rocks, boulders and sculptured bed rock varyingly contributed to the high bottom relief found at Teahwhit Hd., Rock 305, Cape Johnson, Cape Alava, Point of the Arches, Makah Bay and the Neah Bay outside site. Neah Bay (inside) had a hardpan and bed rock bottom with numerous low ridges and occasional boulders.

Table 2. Total prey biomass (means and SD) and size distributions increase greatly north of the sea otter range, were generally lower within the secondary ranges and lowest within the primary range. Percentages of prey items larger than 5 cm observed consumed by feeding sea otters (Bowlby and Troutman Washington State Dept. of Wildlife unpublished) reflect the reduce prey sizes found at sites within the primary range and the otters' preference for larger prey items.

Sea Otter Prey Biomass & Size Distributions

Site	Biomass — total biomass g/m²	Size — benthic survey percent prey ind. >5 cm	Size — feeding otters percent prey ind. >5 cm
sites north and outside of the sea otter range			
Neah Bay inside Makah reserve	661 (158.6)	83 %	
Neah Bay outside Makah reserve	664 (451.0)	66 %	
Makah Bay	776 (58.1)	87 %	
Anderson Pt.	318 (134.4)	89 %	
northern secondary sea otter range			
Pt. of the Arches	165 (71.1)	92 %	
sites within primary sea otter range			
Cape Alava	98 (42.0)	23 %	45 % n=139
Cape Johnson	31 (42.0)	44 %	73 % n=135
southern secondary sea otter range			
Rock 305	128 (57.6)	43 %	
Teahwhit Head	191 (237.1)	51 %	

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Fin Fish Abundance

Table 3. Significantly more fish were counted along midwater (2x2x50 m) and benthic (2x1x50 m) swimming transects at Cape Alava than either of the other two sites quantitatively samped (ANOVA and Fisher PLSD multiple range test $p \leq 0.01$, means and (SD), n = 3)). Qualitative observations indicated high fish densities at Neah Bay and very low numbers at Teahwhit Hd.

Site	black rockfish	striped surfperch	painted greenling	kelp greenling	lingcod	cabezon	kelpfish	total fish	Grand Totals
Neah Bay	very abundant				present				abundant
Anderson Pt.									
midwater	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.5[b] (0.8)
benthic	0.0 (0.0)	0.3 (0.6)	0.0 (0.0)	0.3 (0.6)	0.0 (0.0)	0.0 (0.0)	0.3 (0.6)	1.0 (1.0)	
			sites north of sea otter range						
Cape Alava									
midwater	2.3 (2.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2.3 (2.1)	4.8[a] (3.2)
benthic	3.7 (1.5)	2.3 (1.2)	0.7 (0.6)	0.0 (0.0)	0.3 (0.6)	0.3 (0.6)	0.0 (0.0)	7.3 (1.5)	
			sites within primary sea otter range						
Cape Johnson									
midwater	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.2[b] (0.4)
benthic	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.6)	0.3 (0.6)	0.0 (0.0)	0.0 (0.0)	0.3 (0.6)	
			southern secondary range sea otter range						
Teahwhit Hd.	rare	rare		rare	rare				rare

Table 4. Folios red algal cover varied inversely with urchin density where as crustose coralline and bare rock percent cover was positively related to urchin abundance. No relationship was found between urchin densities and brown understory algae or invertebrate cover. Algal and invertebrate cover as determined by point contacts (n = 250 per station) at the three principle study sites (Anderson Pt., Cape Alava and Teahwhit Head). Neah Bay values are based on qualitative observations made while sampling benthic prey. Percent cover sums may exceed 100% due to layering. Superscripts indicate results of ANOVA and Fisher PLSD multiple range test groupings at $p \leq 0.05$ (** $= p \leq 0.01$).

Biotic Cover (percent) at the Principle Study Sites

Site	folios red algae	coralline crust	brown algae	Invertebrates	bare rock
high urchin density ($21\ \text{ind}/\text{m}^2$)					
Neah Bay (inside Makah reserve)	0%	100%	nr	nr	nr
moderate urchin density ($3\ \text{ind}/\text{m}^2$)					
Anderson Pt. (north of otter range)	27%[b**]	18%[a**]	25%[a]	11%[a]	24%[a**]
low urchin densities ($< 0.2\ \text{ind}/\text{m}^2$)					
Cape Alava (within otter range)	73%[a]	5%[b]	14%[b]	8%[a]	10%[b]
Teahwhit Hd. (south of otter range)	66%[a]	9%[b]	34%[a]	4%[b]	13%[b]

nr = not recorded

Table 5. There was no significant difference in percent cover of the annual kelp species *Nereocystis* found in the benthic transect areas at Neah Bay (a site with no otters and high sea urchin densities) and Cape Alava (the site with the highest sea otter numbers and lowest urchin densities) (t-test p = 0.76). September photographs taken annually at a the same site on Tatoosh Island were used as a measure of between year variation in *Nereocystis* cover. The percent cover of the perennial kelp species *Macrocystis* was significantly less in an aerial photograph taken at Cape Alava before the introduction of sea otters than in an aerial photograph of the same site take in 1986, 17 years after the introduction of sea otters to the Washington coast (t-test p = 0.014). (N = number of subsamples taken from each photograph).

Kelp Percent Cover from Aerial Photographs

	Nereocystis			*Macrocystis*	
	Neah Bay Nov 14 1987	Cape Alava Sept 17 1987	Tatoosh Sept 1976-1986	Cape Alava July 13, 1959 (pre-otter)	Cape Alava June 11 1986
mean	31.8%	34.0%	14.4%	31.5%	58.7%
(SD)	(0.5)	(8.8)	(8.6)	(8.8)	(3.2)
N	4	6	6	4	3

Table 6. Depths (means and SD, n = 50 point contacts per site) and substrata distributions (n = 250 point contacts per site) are given for transects at the three principle study sites. The rugosity index, a measure of substratum relief, is the ratio of the contour distance between two points on the sea floor vs. the straight line distance between the points.

Physical Characteristics of the Principle Study Sites

Substrata (percent cover)

Site	depth (m)	rugosity Index	sand & gravel	cobble (5-10 cm)	small rocks (10-50 cm)	large rocks (50-150 cm)	boulders (>150 cm)	bed rock
Anderson Pt. north of otter range	4.0 (0.43)	1.2 (0.08)	6%	18%	22%	16%	6%	28%
Cape Alava within otter range	4.8 (0.52)	1.4 (0.14)	0%	14%	10%	28%	44%	4%
Teahwhit Hd. south of otter range	4.4 (0.44)	1.4 (0.09)	0%	4%	4%	8%	38%	42%

4. Discussion
4.1. Prey Abundance

As in other studies comparing areas with and without sea otters (Estes and Palmisano 1974, Estes et al. 1978, Stewart et al. 1982, Kvitek et al. in review) results of this survey suggest that sea otters have greatly reduced their prey within their present range (Figure 2). The general pattern that emerges is one of very low prey numbers and small prey sizes within the primary range versus dramatically higher prey numbers, sizes and biomass outside the range to the north and moderately larger prey sizes and higher biomass within the secondary range (Table 2). Jameson et al.'s (in review) survey of the Washington otter population and habitat in 1985 described the Cape Alava area as the primary range of the population with characteristicly low prey densities. Cape Johnson, however, was described as a secondary site typical of one recently occupied by otters due to the observed abundance of large and accessible prey, especially red sea urchins. A more recent survey of sea otter distribution along the coast has reclassified Cape Johnson as a primary otter area and indicate that the bulk of the otter population now moves seasonally between Cape Johnson in the summer and Cape Alava during the winter (Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data). Our benthic prey survey results at Cape Johnson are consistent with this hypothesis; unlike Jameson et al.'s earlier qualitative findings, we found Cape Johnson to have the lowest prey numbers and biomass of any site surveyed. Indeed, no red urchins were seen anywhere in the area. The few urchins (greens, purples and reds) that were found at otter sites were always in crevices or within rock burrows and thus inaccessible to sea otters. This is in stark contrast to areas outside the otters' range where the great majority of urchins of all species were sufficiently exposed to be accessible to otters.

The relatively greater abundance of small sized prey at primary range sites was reflected in the observed diets of the feeding otters (Table 2). At Cape Alava where only 23% of the prey sampled was greater than 5cm in length, 55% of prey items observed being consumed by otters were less than 5 cm (Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data). At Cape Johnson where the proportion of prey larger than 5 cm was 62% higher than at Cape Alava, the proportion of prey larger than 5cm consumed by otters was also higher (91%) than at Cape Alava. The fact that at both primary otter sites the proportion of consumed items larger than 5 cm was higher than the proportion of this size range found in the available prey indicates that the otters were preferentially selecting larger prey sizes.

4.2. Community Structure

The sea otter's ability to greatly reduce densities of invertebrate grazers, especially sea urchins, has long been implicated as an important factor in determining the structure of nearshore algal communities (Estes and Palmisano 1974, Estes et al. 1978, Stewart et al. 1982). Areas with otters are generally portrayed as having low numbers of invertebrate grazers and abundant algal cover, whereas in areas without otters, grazing pressure has been shown to greatly limits algal biomass (Duggins 1980, Dayton 1975). Our results both support and contradict this generalized view. As described above and in the other studies mentioned, sea urchin densities varied inversely with otter

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presence. Consistent with the otter/urchin/algal paradigm we found a negative relationship between urchin densities and folios red algal cover and a positive one between urchins and coralline crust cover (Table 4). This is understandable given the relative susceptibility of these two algal groups to urchin grazing. However, with respect to kelps the pattern was not as clear cut. Although comparisons of *Macrocystis* cover at Cape Alava before and after the introduction of sea otters to the area indicates a significant increase in percent cover, no difference was found in *Nereocystis* cover between Neah Bay, which had the highest concentrations of urchins found and Cape Alava, the longest occupied otter site and having virtually no urchins.

There are several possible explanations for this apparent contradiction. *Nereocystis* is known to be able to achieve a size refuge from urchin grazing (Duggins 1981); urchins avoid adult *Nereocystis* stipes and hold fasts in preference to young plants and other species. This is not the case with *Macrocystis* ; urchins have been known to mow down large stands of adult plants. Thus, on an exposed coast such as the Olympic Peninsula, if surge conditions in spring prevent urchins from foraging during the time of *Nereocystis* recruitment and early growth, this annual plant may gain enough of a head start to out-grow the urchins by the time conditions are calm enough for the grazers to begin foraging. This would explain why *Nereocystis* is so abundant at Neah Bay while folios reds are scarce. Even if the urchins are restricted from foraging until summer, they can always graze down the reds, but not the bull kelp.

Another possible explanation for the seemingly anomalous presence of dense *Nereocystis* at Neah Bay, is that 1987 was an extremely good year for this species. Although there are no hard data to support this claim, urchin fishermen at Neah Bay and Washington State Dept. of Fisheries surveyors (Alex Bradbury, Brinnin Shellfish lab) have commented on the unusually dense cover of *Nereocystis* in 1987. In addition, we have shown *Nereocystis* cover to be quite variable at a site on Tatoosh Island not far from Neah Bay (Table 5). It is therefore possible that kelp recruitment and growth overwhelmed the urchins in 1987, particularly if extensive urchin movement is restricted to the calmer months of summer.

Evidence suggesting a new mechanism by which sea otters may significantly alter the structure of their prey communities was observed during this study. At Cape Alava, considerable numbers of the large rocks in the area had sessile invertebrates (normally found on the undersurfaces) growing on the tops and folios red algal species attached to the undersides. Due to the distribution of available prey, it appears as though the otters were turning over very large rocks to obtain hidden food items (e.g. crabs, octopus, *Cucumaria*). Rock rolling by waves in both the intertidal (Sousa 1979) and subtidal has been shown to influence patterns of species richness and abundance. Otter disturbance of this sort may produce considerably different patterns than wave disturbance because they are mostly likely to occur at opposite times of the year, i.e. otters of the Washington coast appear to shift there range seasonally to avoid exposure to the prevailing swell (Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data).

4.3. The Sea Otters' Future on the Washington Coast

The comparison of otter distribution versus their prey along the outer coast (Figure 2) poses two questions. 1) If there is several times the amount of available food present at sites north of the sea otters' range, why do they remain at sites where prey is small and scarce; Cape Alava in the winter and Cape Johnson during the summer? 2) Given that the size of the otter population has been increasing and that their prey resources have been and will continue to decrease, what changes might we expect to see in the future?

Firstly, although prey may be scarce at the two otter sites, both afford protection from swell due to the presence of off-shore islands and rocks. Inspection of the Washington coastline shows Cape Alava to be the best protect site in any swell condition. The Bodeltah Islands and Ozette Island are able to provide shelter both from the sw swells of winter and the nw seas of summer. During the Olympic National Parks 1986 New Years aerial bald eagle count most of the otters seen were in the lee of Ozette Island (Ed Whitaker, Park Ranger, Mora, ONP, pers. com.). This protection combined with a very extensive, shallow subtidal boulder field providing ideal habitat for prey organisms, made Cape Alava the most likely place on the coast to be colonized by the translocated sea otters, and this is apparently what happened (Jameson et al. 1982, Jameson et al. in review). Cape Johnson, on the other hand is protected only from nw swell. This may explain why it has only been recently invaded by otters and used primarily as a summer area. In addition to protection and prey habitat, both these sites are as isolate from boat traffic and human contact as possible on the coast. A shift either north or south would take them closer to the fishing ports of Neah Bay and LaPush respectively where native Americans maintain an active set-net fishery. Gill net fishing has been implicated in restricting the growth of the California otter population (USFWS 1986).

Another possible but unlikely explanation for why otters have remained at these two sites, is that they may be relying on large but more mobile and cryptic prey than we observed in our survey, such as octopus, large crab, clams or fish. However, surface observations at both these sites indicate that the first three categories, while present in the otters' diets, represented a minority of the prey items and fish were never eaten (Bowlby and Troutman, Washington State Dept. of Wildlife unpublished data). Furthermore, in our initial survey of each of these sites, we covered a very large area looking in many crevices and other likely places for these species and found none. This was not true outside the otter range, where even though octopus and crab were not found along the transect lines, they were encountered relatively frequently in the general survey of the sites.

Not withstanding the otters' apparent reluctance to move, what alternatives are available given their diminishing prey resources? There are several. Some or all of the otters may continue to use Cape Alava under at least the following conditions. If the entire population remains it will probably be at a reduce population growth rate unless they are able to exploit a previously untapped and abundant prey resource. It is believed that some Aleutian otter populations switched to eating fish as their invertebrate prey became scarce and fish numbers increased along with the kelp cover (Estes et al. 1981). This

may occur at Cape Alava where we found several species of large fish to be very abundant and easily approachable (Table 3). Otters may also continue to use Cape Alava as strictly a winter site or a female site as other populations have done with long occupied areas (Garshelis 1983) while the bulk of the population moves to one of the richer prey areas to the north either permanently or seasonally.

If the otters shift their range, they will not be passive participants in the communities they invade, and it is therefore worth considering where they may go and what the consequences might be. A move south would appear to gain them very little; more people, more boats, more nets, generally less protection from swell, and not much more food until they get all the way down into the clam beds of Grays Harbor and Willapa Bay. Sites to the north, however seem more promising on the surface; much more food, large easily caught prey, fairly good protection from swell once inside Anderson Point, and especially inside the Strait of Juan de Fuca. However, the intense native American set-net fishery operating out of Neah Bay, and the new and growing sea urchin fishery developing in the Strait may present a barrier to the otters.

Given all these factors; an expanding otter population, diminished prey within the otters' range, a gradient of both prey abundance and human fishing activity increasing to the north, and the tendency for otters and man to compete for the same resources, the stage appears set for a new round of man/otter conflicts. Because we have seen such interactions raise hot blood on both sides in the past (see Estes and VanBlaricom 1985 for review), perhaps now is the time to plan for the future management of these potential conflicts.

Appendix

Table 1. Taxonomic abbreviation codes for species names listed in the appendix tables.

Group	Code	Species
brown algae	Ld	*Laminaria dentigera*
	Lg	*Laminaria groenlandica*
	Mi	*Macrocystis integrifolia*
	Nl	*Nereocyctis lutkeona*
	Pc	*Pterygophora californica*
crabs	C sp	*Cancer* sp.
	Sa	*Scyra acutifrons*
tunicate	Sm	*Styela montereyensis*
sea stars	Di	*Dermasterias imbricata*
	Et	*Evasterias troschelii*
	Hl	*Henricia leviuscula*
	Lh	*Leptasteria hexactis*
	Ok	*Orthasterias koehleri*
	Ph	*Pycnopodia helianthoides*
	Po	*Pisaster ochraceus*
	So d	*Solaster dawsoni*
	Ss	*Solaster stimpsoni*
urchins	Sd	*Strongylocentrotus droebachiensis*
	Sf	*Strongylocentrotus franciscanus*
	Sp	*Strongylocentrotus purpuratus*
cucumbers	Cm	*Cucumaria miniata*
	Eq	*Eupentacta quinquesemita*
gastropods	Tb	*Tegula brunnea*
	Cl	*Calliostoma ligatum*
	Cf	*Ceratostoma foliatum*
	Ol	*Ocenebra lurida*
limpets	Am	*Acmaea mitra*
	Ci	*Collisella instabilis*
	Da	*Diodora aspera*
chitons	Cs	*Cryptochiton stellarii*
	M l	*Mopalia lignosa*
	Pv	*Placiphorella velata*
	Tl	*Tonicella lineata*
bivalves	Hg	*Hinnites giganteus*

Appendix

Table 2. Invertebrate abundances measured along transects at Olympic Peninsula study sites (means and SD's). (N = number of square meter quadrats, ns = not sampled). See taxonomic abbreviation key for species names (appendix table 1).

Invertebrate Species Abundances (Ind/m²)

	N	crab Sa	C sp	tunicate Sm	sea stars Dl	Et	Hl	Lh	Ok	Ph	Po	So d	Ss
Neah Bay (inside)	50												
mean		0	0	0	0.06	0	0.24	0	0.14	0.22	0.02	0	0
SD		(0.0)	(0.0)	(0.0)	(0.2)	(0.0)	(0.5)	(0.0)	(0.4)	(0.5)	(0.1)	(0.0)	(0.0)
Neah Bay (outside)	50												
mean		0	0	0	0.10	0	0.20	0	0.12	0.28	0.04	0.02	0
SD		(0.0)	(0.0)	(0.0)	(0.3)	(0.0)	(0.5)	(0.0)	(0.4)	(0.6)	(0.3)	(0.1)	(0.0)
Makah Bay	49												
mean		0	0	0.1	0	0	0.18	0.04	0	0.02	0.06	0	0
SD		(0.0)	(0.0)	(0.4)	(0.0)	(0.0)	(0.4)	(0.2)	(0.0)	(0.1)	(0.2)	(0.0)	(0.0)
Anderson Pt.	99												
mean		0	0	0.47	0.08	0.01	0.21	0.04	0	0.11	0.01	0	0
SD		(0.0)	(0.0)	(0.9)	(0.3)	(0.1)	(0.5)	(0.2)	(0.0)	(0.3)	(0.1)	(0.0)	(0.0)
Pt. of Arches	35												
mean		0	0	0	0	0	0.1	0	0	0	0	0	0
SD		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.3)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Cape Alava	100												
mean		0.17	0.01	0.39	0	0.16	0.35	0.56	0	0.05	0.1	0	0
SD		(0.5)	(0.1)	(0.6)	(0.0)	(0.5)	(0.7)	(1.2)	(0.0)	(0.2)	(0.4)	(0.0)	(0.0)
Cape Johnson	50												
mean		0	0	0.52	0.02	0.06	0.14	0.02	0	0.06	0	0	0.02
SD		(0.0)	(0.0)	(1.0)	(0.1)	(0.2)	(0.4)	(0.1)	(0.0)	(0.2)	(0.0)	(0.0)	(0.1)
Rock 305	50												
mean		0.02	0	1.96	0	0.08	0.36	0.1	0	0.02	0.04	0.02	0
SD		(0.1)	(0.0)	(2.3)	(0.0)	(0.3)	(0.7)	(0.6)	(0.0)	(0.1)	(0.2)	(0.1)	(0.0)
Teahwhit Head	100												
mean		0.14	0.01	0.56	0.03	0.07	0.51	0.12	0	0.01	0.13	0.01	0
SD		(0.5)	(0.1)	(0.9)	(0.2)	(0.3)	(0.9)	(0.6)	(0.0)	(0.1)	(0.4)	(0.1)	(0.0)

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Table 2. (continued)

Invertebrate Species Abundances (ind/m²)

Site	N	urchins			cucumbers			gastropods				limpets			Cs	chitons			bivalve
		Sd	Sf	Sp	Cm	Eq	Sc	Tb	Cl	Cf	Ng	Am	Cl	Da		Ml	Pv	Tl	Hg
Neah Bay (inside) mean	50	0	21.1	0	0	0	0.24				0.70	ns	ns	0.24	0.04	ns	ns	ns	0
SD		(0.0)	(9.4)	(0.0)	(0.0)	(0.0)	(0.6)				(2.2)			(0.6)	(0.2)				(0.0)
Neah Bay (outside) mean	50	0.46	12.3	0	0	0	0.36					ns	ns	0.40	0.04	ns	ns	ns	0
SD		(0.9)	(9.7)	(0.0)	(0.0)	(0.0)	(0.7)							(0.9)	(0.2)				(0.0)
Makah Bay mean	49	0	6.7	0.39	0.1	0	0.03	0.08	0.51	0	0	0.43	0.08	0.16	0.06	0.04	0	0.29	0.02
SD		(0.0)	(3.6)	(0.8)	(0.3)	(0.0)	(0.2)	(0.4)	(1.7)	(0.0)	(0.0)	(0.6)	(0.4)	(0.4)	(0.2)	(0.2)	(0.0)	(0.7)	(0.1)
Anderson Pt. mean	99	0	3.3	0	0.27	0	0.03	0	0.18	0.03	0.08	0.06	0	0	0.02	0	0	0.04	0
SD		(0.0)	(2.6)	(0.0)	(0.6)	(0.0)	(0.2)	(0.0)	(0.7)	(0.2)	(0.3)	(0.3)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.2)	(0.0)
Pt. of Arches mean	35	0	4.4	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0	0	0
SD		(0.0)	(5.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.3)	(0.0)	(0.0)	(0.0)	(0.0)
Cape Alava mean	100	0.04	0.02	0.43	0.93	0.06	0	0.37	3.16	0.35	0.1	0.14	0.25	0.26	0	0.19	0.01	0.39	0.03
SD		(0.3)	(0.1)	(1.8)	(1.7)	(0.2)	(0.0)	(1.4)	(4.1)	(0.7)	(0.6)	(0.4)	(1.0)	(0.6)	(0.0)	(0.4)	(0.1)	(0.6)	(0.2)
Cape Johnson mean	50	0.02	0	0.1	0.22	0	0	0.02	0.1	0.04	0.16	0.02	0.12	0.02	0.02	0.1	0.02	0.08	0.14
SD		(0.1)	(0.0)	(0.5)	(0.8)	(0.0)	(0.0)	(0.1)	(0.4)	(0.2)	(0.4)	(0.1)	(0.4)	(0.1)	(0.1)	(0.3)	(0.1)	(0.3)	(0.8)
Rock 305 mean	50	0.04	0.1	0.34	1.06	0	0	0	0.56	0.3	0.32	0.48	0.42	0.06	0.1	0.06	0.06	0.18	0.1
SD		(0.2)	(0.3)	(1.0)	(1.8)	(0.0)	(0.0)	(0.0)	(1.4)	(0.9)	(0.8)	(1.0)	(1.4)	(0.2)	(0.3)	(0.2)	(0.2)	(0.7)	(0.4)
Teahwhit Head mean	100	0.05	0.22	0.06	1.31	0	0	0	1.26	0.2	0.55	0.03	0.01	0.02	0.26	0.03	0.02	0.05	0.19
SD		(0.2)	(0.6)	(0.3)	(2.2)	(0.0)	(0.0)	(0.0)	(2.2)	(0.5)	(2.7)	(0.2)	(0.1)	(0.1)	(0.5)	(0.2)	(0.1)	(0.4)	(0.5)

Table 3. Brown algal species abundances (means and SD's) measured along transects at study sites along the outer coast of the Olympic Peninsula. (N = number of meter square quadrats sampled). See taxonomic abbreviation key (appendix table 1) for species names.

Brown Algae Abundances (ind/m^2)

Sites	N	Ld	Lg	Mi	Nl	Pc
north of present sea otter range						
Makah Bay	49					
mean		0.1	0.92	0	0.16	0.04
SD		(0.5)	(4.6)	(0.0)	(0.9)	(0.2)
Anderson Pt.	99					
mean		0	2.0	0	0.34	0.45
SD		(0.0)	(10.5)	(0.0)	(1.0)	(2.3)
northern secondary sea otter range						
Pt. of Arches	35					
mean		0.22	0.08	0	0.06	0
SD		(1.3)	(0.5)	(0.0)	(0.2)	(0.0)
within primary sea otter range						
Cape Alava	100					
mean		2.34	1.09	0.06	0.1	0.54
SD		(4.9)	(3.8)	(0.6)	(0.4)	(1.0)
Cape Johnson	50					
mean		0.12	0.04	0.28	0.04	0.54 .
SD		(0.4)	(0.3)	(0.7)	(0.2)	(1.6)
southern secondary sea otter range						
Rock 305	50					
mean		0.94	0.14	0	0.52	1.34
SD		(1.3)	(0.5)	(0.0)	(1.2)	(2.7)
Teahwhit Head	100					
mean		2.06	0.23	0	0.09	2.43
SD		(3.5)	(0.9)	(0.0)	(0.5)	(5.4)

Appendix

Table 4. All species listed below were observed at least once during the subtidal survey between Teahwhit Head to the south and Makah Bay to the north. Relative abundances are based on the following rankings of encounters per dive: r = rare (< 1/dive); p = present (1-5/dive); c = common (5-50/dive); a = abundant (50-100/dive); very abundant (>100/dive).

Faunal Species Observed and their Relative Abundances

species	relative abundance	notes
Brachiopods		
Terebratalia transversa	r	
Bryozoans		
Aglaoephenia spp.	p	
Cnidarians		
Anthazoans		
Anthopleura elegantissima	p	
Anthopleura xanthogrammica	c	
Balanophyllia elegans	c	
Corynactis californica	r	
Epiactis proliferata	p	
Gersemia rubiformis	p	
Metridium senile	r	
Urticina crassicornis	p	
Urticina lofotensis	r	
Scyphozoans		
Thaumatoscyphus hexaradiatus	p	
Crustaceans		
Amphithoe sp.	r	
Balanus sp.	p	
Cancer oregonensis	c	(generally found only in rock burrow holes inaccessible to sea otters)
Cryptolithodes spp.	r	
Hermit crabs	c	
Idotea resecata	r	
Mimulus foliatus	r	
Pandalus sp.	r	
Scyra acutifrons	p-c	
Echinoderms		
Asteroids		
Dermasterias imbricata	p	
Evasterias troschelii	c	
Henricia leviuscula	c	
Leptasterias hexactis	c	
Orthasterias koehleri	r	
Patiria miniata	r	
Pisaster ochraceas	p	

Table 4. (continued)

species	relative abundance	notes
Pycnopodia helianthoides	p	
Solaster dawsoni	r	
Solaster stimpsoni	p	
Sea Urchins		
Strongylocentrotus drobachiensis	p	
Strongylocentrotus franciscanus	r-v	
Strongylocentrotus purpuratus	p	(generally found only in rock burrow holes inaccessible to sea otters)
Sea Cucumbers		
Cucumaria miniata	a	
Eupentacta quinquesemita	p	
Stichopus californicus	r-c	
Ophiuroids	p	
Hydrozoans		
Allepora porphyra	r	
Tubularia crocea	p	
Molluscs		
Gastropods		
Amphissa columbiana	p	
Calliostoma ligatum	c	
Ceratostoma foliatum	c	
Crepidula adunca	p	
Ocenebra lurida	p	
Opalia chacei	p	
Searlesia dira	r	
Tegula brunnea	p	
Chitons		
Crypotochiton stelleri	p	
Mopalia lignosa	p-c	
Placiphorella velata	p	
Tonicella lineata	p	
Limpets		
Acmaea mitra	c	
Colisella instabilis	c	
Diodora aspera	c	
Nudibranchs		
Anisidoris nobilis	p	
Antiopella barbarensis	p	
Archidoris montereyensis	c	
Archidoris odhneri	p	
Dirona albolineata	p	
Laila cockerelli	p	
Triopha catalinae	c	
Tritonia festiva	p	

Appendix

Table 4. (continued)

species	relative abundance	notes
Bivalves		
Hinnites giganteus	p	
Nemerteans spp.	p	
Polychaetes		
Dodecaceria fewkesi	p	
Eudistylia spp.	p	
Myxicola infundibulum	p	
Phragmatopoma californica	p	
Sponges		
Tetilla arb	p	
Isodictya quatsinoensis	p	
Tunicates		
Styela montereyensis	a	
Perophora annectens	p	
Metanfrocarpa taylori	p	
Fish		
Damalicthys vacca	r	
Embiotica lateralis	p	
Gibbonsia spp.	r	
Gobieosox spp.	r	
Hexagrammos decagrammus	c	
Ophiodon elongatus	p	
Oxylebius pictus	r	
Scorpaenichthys marmoratus	p	
Sebastes auriculatus	r	
S. caurinus	r	
S. melanops	c	
S. nebulosus	p	

Appendix

Table 5. All species listed below were observed at least once during the subtidal survey along the outer coast of the Olympic Pennisula between Teahwhit Head to the south and Makah Bay to the north.

Algal Species Observed

species

brown algae
>   *Alaria marginata*
>   *Costaria costata*
>   *Desmarestia ligulata* var. *ligulata*
>   *Egregia menziesii*
>   *Laminaria dentigera*
>   *Laminaria groenlandica*
>   *Macrocystis integrifolia*
>   *Nereocystis luetkeana*
>   *Pleurophycus gardneri*
>   *Pterygophora california*

green algae
>   *Derbesia marina*
>   *Ulva* spp.

red algae
>   *Botryoglossum falowianum*
>   *B. ruprechtianium*
>   *Erythrophyllum delesseriodes*
>   *Iridea* spp.
>   *Odonthalia washingtoniensis*
>   *Plocamium cartilagineum*
>   *Prionitis lanceolata*
>   *Rhodymenia californica*
>   *R.* spp.
>   articulated coralline algae
>   encrusting coralline algae

Table 6. The regression equations relate wet meat weight (grams) to size (maximum linear dimension unless otherwise stated) for spp. collected along the outer coast of the Olympic Peninsula between Teahwhit Head to the south and Makah Bay to the north.

Faunal Species Size and Weight Regressions

species	regression	r	N	length range
Acmaea mitra	wt = 4.827 x 10^{-6} x shell length (mm)$^{3.9}$	1.0	5	13-32 mm
Calliostoma liniata	wt = 0.0038 x 10$^{0.1273}$ $^{x\ shell\ length\ (mm)}$	1.0	4	11-19 mm
Ceratostoma foliatum	wt = 5.313 x 10^{-6} x shell length (mm)$^{3.313}$	0.98	3	31-71 mm
Cucumaria miniata	wt = 0.036 x 10^{-6} x contracted body length (mm)$^{1.694}$	0.86	5	71-115 mm
Diadora aspera	wt = 0.1486 x 10$^{0.0359}$ $^{x\ shell\ length\ (mm)}$	1.0	5	22-67 mm
Mopalia lignosa	wt = 2.6 x 10^{-6} x shell length (mm)$^{3.86}$	0.98	5	22-49 mm
Tegula brunnea	wt = 2.8 x 10^{-6} x shell length (mm)$^{4.077}$	1.0	5	17-33 mm
Strongylocentrotus franciscanus	wt = 1.49 x 10$^{0.014}$ $^{x\ test\ diameter\ (mm)}$			(Bernard and Miller, 1973)

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Appendix 4

Field necropsy reports of two dead sea otters recovered
in Washington State in 1986 and 1987.

<u>Date</u> -	24 June 1986	21 July 1987
<u>Field Collection</u> <u>Number</u> -	398	425
<u>Location</u> -	1 km north of Sand Point, Olympic Nat. Park, WA	2 km north of Point of the Arches, Olympic Nat. Park, WA
<u>Sex</u> -	Female	Male
<u>General</u> <u>Condition</u> -	Estimated dead 5 days; Pelage sloughing; no external wounds found.	Freshly dead; rigor mortis incomplete; no external wounds found.

<u>Measurements (cm):</u>

snout-tail tip -	132	131.2
tail length -	29	23
hind flipper length		
to patella -	22	--
to pelvis -	34	40.7
hind flipper width		
spread -	--	19.5
fore flipper length		
anterior -	18	22.8
ear length -	--	2.5
axillary girth -	--	56.6
pelvic girth -	--	62.3
neck girth -	--	40.7

<u>Internal</u>
<u>Condition</u> - nonparous female, small
uterus and ovaries showing
no sign of corporea lutea or
albicantia; heart and kidneys
appeared normal externally
and in x-section; other
organs too autolysed for
examination; stomach empty;
no sign of trauma.

all organs ap-
peared normal ex-
ternally and in
x-section; stomach
empty; intestines
contained minimum
of 41 clams
(*Protothaca stam-
inea*); exam and
x-rays revealed no
cause of death.

Samples
  Collected - entire skeleton   tissus samples of
                                                    major organs frozen;
                                                    entire carcass frozen

Comments - carcass discovered June 22;   stranding occurred
        reported June 23; necropsied   approximately 1045 hrs
        June 24.   on July 21; necropsied
                                                    1630 hrs.

DATE DUE